PHYSICAL GEOGRAPHY.

PREFACE.

The present work is one of a series of articles written, at the request of the editors of the Encyclopædia Britannica, for publication in the new edition of that digest, where it accordingly first appeared in 1859. Being desirous of publishing it in a separate form they have obligingly afforded the author an opportunity during the passing of the sheets through the press, of revising them, which he has so far availed himself of as to make some not very important corrections where they appeared to be needed, and to insert some few additional notices or remarks—chiefly in the form of notes. These are sufficiently distinguished, where they occur, from the original text, but are not such, either in number or importance, to destroy the identity of the work with the original article. To write a complete treatise on Physical Geography though a noble, would have been a most arduous task, and one for

which the author, even had he time and facilities fo the undertaking, might well doubt his qualificatior As a preparation for a more extended study of th original works of the great authorities on the subject this volume will perhaps not be without its utility Some of the views taken in it may possibly be con sidered as having a claim to originality; and the dis cussion on the subject of the action of winds in producing the ocean currents, though in effect only a defence of the received theory, will not probably be thought superfluous by those who may have had thei confidence in that theory shaken by the manner in which it has of late been called in question.

In spelling the names of Indian mountains, rivers and places, the system of Sir W. Jones, founded on th Italian pronunciation, has been adhered to—the aban donment of which for our confused and precariou English orthography is deeply to be regretted, inasmuc as it goes to render oral communication on Indian sul jects between an Englishman and a foreigner next t impossible. I regret, too, to be obliged to differ fro most of our geologists in retaining the etymologica spelling of such words as meiocene, pleiocene, deinothe rium, etc., not as a matter of mere pedantry, but becaus

it is growing into a practice to pronounce them as French words, owing to the omission of the first letter of the Greek diphthong. When a native, or otherwise anciently received name for a mountain, river, or lake in any part of the world, not absolutely cacophonous, exists on record, it is systematically preferred to our recent English or American *nicknames* of the same object.

COLLINGWOOD, APRIL 5, 1861.

ERRATA

Page 82, line 7 from bottom, *for* botom *read* bottom.

Page 115, line 11, *for* Tromboro *read* Tomboro.

Page 180, line 1 to 10, the latter portion of § 201, from the word Petroleum to the end, should be marked as an insertion into the original text by being placed between brackets [ ].

Page 165, line 18, *for* Daurian *read* Dahurian

Page 201, line 11, *for* Bolat *read* Bolor.

PHYSICAL GEOGRAPHY.

GEOGRAPHY, or a description of the earth, may be considered under several distinct points of view, necessitated by the nature of so extensive a subject; three of which, however, are well distinguished from each other, and present it under aspects of primary importance, practical and scientific.

(1.) *Political Geography* considers the surface of our globe as parcelled out into states and empires, inhabited by communities and races of the great human family, variously affected by the different characters of soil and climate, by which their habits, manners, and occupations are modified; and continually encroaching on each other, and altering their mutual boundaries by conquest or colonization. This view of geography is therefore essentially arbitrary and conventional, as well as in a perpetual state of change from age to age. Commerce and statistics, aptitude for military occupation or defence, facilities for internal and external communication,

and products available for human wants, form its chief subject-matter; and cities and towns, the centres of population, power, and enlightenment, its most important landmarks.

(2.) *Descriptive Geography*, while it neglects the boundaries of states, or uses them only for such convenience as they may afford for the subdivision of its subject, concerns itself principally with the exact delineation, in charts, of the coast-lines of continents and islands, internal seas or lakes—with the courses and embankments of rivers, the configuration of the surface of the land, as consisting of mountains, valleys, and plains, whether delineated in charts by conventional shading, or marked out by level lines, or described in words. Its scope embraces, moreover, a particular and detailed account of their external aspect, soil, scenery, and animal, vegetable, and mineral productions, which characterize and diversify each district; irrespective, or but little respective, of their uses to man, or of their connection *inter se*, or of the causes which have operated to produce them. Of all these, it would be the business of a perfect "Descriptive Geography" to exhibit a true and faithful picture, a sort of daguerreotype, without note or comment.

(3.) Such comment, or at least one of such comments, it is the object of PHYSICAL GEOGRAPHY to supply. Taking for granted such knowledge as we possess of the

general laws of physics, and of the mode in which they are carried out into action, under given circumstances of time and place; and basing itself on the detail of particular features afforded by the last-mentioned department of the general science—it calls attention to those laws as displayed in operation whenever, so to speak, they project in relief, and stand forward as luminiferous examples (*instantiæ luciferæ*) of the application of theoretical views on the great scale. Its aim is to exhibit the heap of particulars gathered and stored up by descriptive geography, as constituting a harmonious whole, bound together by mutual relations and interagencies, and subordinate to a great scheme of providential arrangement. And this it does, not by going over the items *seriatim*, and following up the order of description with a running comment, but, by seizing on whatever is illustrative at one point, and comparing it with what is similarly illustrative at another; by bringing into notice the causes which either evidently are acting, or by reasonable implication must be presumed to have acted, to produce the more striking and characteristic phænomena of such regions as offer anything remarkable; and of such as do not, by shewing how this very monotony is itself the result of a prevalent uniformity of causation; of which a rational account can be rendered, and which it illustrates no less strikingly by the absence of salient features than the complica-

tions observable elsewhere do by their number and variety.

(4.) With these general laws, with the principles which govern their application, and with the methods which science affords of deductively tracing out their application from the abstract enunciation of the laws themselves, under specified circumstances, to precise and intelligible results, the physical geographer must be conversant; so far at least, that he must possess a familiar acquaintance with physical principles, and such an insight into their application as shall enable him to take on well-grounded trust the conclusions of others more advanced in such knowledge. For all such knowledge in its detail, we must refer our readers to those works which treat specifically of the several branches of physics, appeal to which is involved in any part of our treatment of the subject. But some of its leading points require to be briefly recapitulated, as embodying the first elements and material *out of* which, as well as exhibiting the ground-plan and general design *on* which, the whole superstructure has to be raised.

(5.) And first, then—from ASTRONOMY we learn that the figure of this our earth is nearly that of an oblate ellipsoid of revolution, having an equitorial diameter of 7925·65 British statute miles, and a polar one of 7899·17 such miles, or, neglecting the ellipticity, which is only one 290th part of the mean of these diameters—nearly

that of a globe of equal bulk, whose diameter (calculated so as to satisfy that condition), would be 7916·0 statute miles.* Calculating on this *datum*, we find that its superficial area (sea and land both included) is about 197 millions of *square*, and its solid contents about 260 thousand millions of *cubic* statute miles. Its average density, as collected from a mean of several independent determinations, differing much less *inter se* than the evident difficulty of such an inquiry would lead us to expect, may be taken at 5½ times that of pure water, which is fully double that of the average material of the earths and rocks of which its surface consists. And hence we may compute its absolute weight, which is about 5852 trillions (5852×10^{18}) of tons; while at the same time we conclude either that the interior portions of it are to some considerable extent metallic; or, which is more probable, condensed by the immense pressure they have to sustain, some conception of which may be formed from this—that if a channel, less than a square mile in sectional area, were opened from the bottom of the sea to the centre of the earth, the whole ocean would flow into it—taking, that is to say, the increase of density of water (according to the experiments of Perkins) at 0·474 per cent. for every additional 100 atmo-

* Equivalent to 7908·1 *British metrical miles*, taking the metrical inch as one 500,000,000th part of the earth's polar axis.—(*Athenæum*, No. 1696, p. 581.)

spheres of pressure, and *supposing the same ratio to hold good under all pressures.* This, of course, cannot be really the case. One of two things must happen: either the water would be compressed into solidity, or must be sustained from so doing by an increased elasticity, the effect of an exceedingly high temperature.

(6.) This, indeed, we have every reason to believe, really exists within the earth. Not only is it a general fact that the thermometric temperature of the ground does increase in descending, in all regions of the globe wherever deep mines have been sunk, or borings executed, at an average rate of about 1° Fahr. for every 90 feet of depth; and not only do the phenomena of volcanoes and hot springs indicate unmistakeably the still further increase of heat beyond the reach of artificial excavation, but the fact itself, that the mean density of the globe is so small as 5½, must be held conclusive evidence of an excessive internal temperature. It is not by solidifying that fluids can escape from further condensation. Solids, as well as fluids, are compressible; even the densest metals increase in density by hammering; and though the rate of compressibility of matter in the solid state is vastly smaller than in the fluid, it is not conceivable that, under a pressure of 300,000 atmospheres, much that we usually look upon as very solid substance would not be reduced to a small fraction of its bulk. Nor will it avail to look

to the support of the upper strata by the spherically vaulted form of the lower, so as to relieve the internal portions of their load. The lateral thrust, in an equilibrated arch or vault, vastly exceeds the weight laid upon it; so that nohow can the conclusion be evaded that the internal portions of the earth, whether fluid or solid, actually do sustain this almost inconceivable force, and we can look to no power but the expansive force of heat which can counteract its condensing effect.

(7.) Whatever be the intensity of that heat, and whether the central portions of the globe be solid or fluid, there can be no doubt that the density of the materials of which it consists in proceeding downwards, must follow an increasing progression.* ASTRONOMY, grounding its conclusion on some observed facts in the moon's motion, otherwise inexplicable, assures us that, as a matter of fact, it does so. This being the case in the absence of any cause to produce disturbance (and we can perceive none of power enough to act at *great* depths,† so as to produce upward currents), the lower strata must preserve their level, and the whole interior

* Professor Roche of Montpellier in a note recently published on the law of the variation of gravity in the interior of the earth, has been led to assign to the whole earth a mean density equal to 2·6 times that of its superficial strata, and a central density five times the latter (or from ten to twelve times that of water at the surface). The mean density he considers to exist at a depth of about a quarter of the radius below the surface.

† Such as exceed 100 miles, for instance.

of the earth, considered on the great scale, must be in a state of absolute quiescence, enough so at least, at all events, to prevent the central heat from being carried to the surface by the material transfer of heated and molten matter. Under such circumstances, we learn from THERMOTICS that the escape of heat from the interior, through the external shell of the earth out into the air, and free space, must be of most inconceivable slowness —so much so, that no appretiable share in producing or maintaining the warmth of the *surface*, can be attributed to it, and that the difference of climates and local temperature is the result entirely of external influences, which it belongs to METEOROLOGY to develope.

(8.) From the principles of DYNAMICS, we learn that the deviation of one 290th from exact sphericity in the earth's figure, is a consequence of its rotation on its axis, and is essential to the maintenance of the equilibrium of the ocean, so that a shifting of the axis would entail the submergence of the existing land, but from the same source we learn that from natural causes (as known to us), no such shifting ever can have taken place, or ever will; and this deduction from theory is confirmed by Astronomy, which shews that the latitudes of places, as determined by the most delicate observation, are absolutely invariable. Were the earth a sphere, this might be drawn into an argument against its internal fluidity, since the external shell, floating on an ocean of fluid,

might at first sight be supposed capable of drifting at random from its relative place, without a displacement of the general axis of rotation. But (even were the conclusion a valid one, which it is not), the rigidity of the elliptic shell which can only *fit* the elliptic (though fluid) supporting nucleus in one position, will act as a retaining force, and prevent any, the smallest deviation; since, to disturb the whole external shell on the whole internal fluid, would be in effect to change the figure of the latter, and call into action all the antagonistic forces which resist such change.

(9.) If then, as GEOLOGY assures us, the continents can be proved by unmistakeable evidence to have been submerged, and the ocean-bed laid dry, not once only, but repeatedly, nay, that the process is actually going on, though slowly, under our eyes, we must look elsewhere than to a change in the axis of rotation for the causes of such a fact.* Yet more, we learn from dynamical principles, that all the influences exterior to the earth, by which the waters of the sea are kept in agitation, act through the intervention of these waters in antagonism to the existence of the continents for the time being, and perpetually tend to degrade and destroy them, and to spread their materials over the bed of the sea, filling

* A change in the axis of symmetrical figure might, no doubt, produce a change in the axis of permanent rotation; but we know of no cause in action having any tendency to produce a change of symmetrical form progressive, however slowly, in one direction.

[illegible] and doing their best to bring on a state of [illegible] smoothness, in which the whole earth would be covered with sea, having a dead level for its bed. The land, then, is maintained in its elevated position by internal force, locally exerted, and varying its locality from age to age, according to laws which belong to the domain of geological, rather than geographical science. Whatever be the nature and ultimate origin of that force, it is manifested to us in action from time to time in the volcano and the earthquake, which thus we learn to regard as very far from purely destructive arrangements *in the great scheme of nature; since, without the agency* of which they are part and parcel, there would by this time have been no dry land whatever. The fact that all our present continents consist of beds or strata, which have resulted from the destruction of former ones, and the distribution of their materials at the bottom of the sea; and of granitic masses forcibly thrust up through those strata, disturbing and dislocating them; leads direct to the conclusion that, had the primeval world been constructed as it now exists, time enough has elapsed, and force enough, directed to that end, been in activity, to have long ago destroyed every vestige of land, but for the reproductive efficacy of these internal forces bringing up continually new lands to replace the old.

(10.) Hence, then, we come to perceive that the actual

configuration of our continents and islands, the coast-lines of our maps, the direction and elevation of our mountain chains, the courses of our rivers and the soundings of our oceans, are not things primordially arranged in the construction of our globe, but results of successive and complex actions on a former state of things; *that* again, of similar actions on another still more remote; and so on till the original and really primeval state is pushed altogether out of sight and beyond the reach even of imagination; while, on the other hand, a similar, and, so far as we can see, an interminable vista is opened out for the future, by which the habitability of our planet is secured amid the total abolition on it of the present theatres of terrestrial life.

(11.) But the revelations of geology do not stop here. They assure us, further, that in each of those successive submersions and reconstructions of the continents, fresh corresponding races of animals, and a new and different clothing of vegetation have been introduced—the one perishing off as the others have come into existence; nay, that even the denizens of the ocean itself have had no exemption from this great law of change—which, however, has not operated, either by a gradually progressive variation of species, nor by a sudden and total abolition of one race, and introduction of another entirely new, but by a series of overlappings, leaving the last portion

of each in co-existence with the earlier members of the newer series.* Higher forms of being, moreover, appear at every stage of the process, up to the final and culminating point of humanity, and the existing order of things. And by the indications afforded by the exhumed remains of these successive creations, the geologist finds himself enabled to co-ordinate the succession of strata, and to assign to each its epoch in the past history of the world.

* This was written previous to the publication of Mr. Darwin's work on the Origin of Species, a work which, whatever its merit or ingenuity, we cannot, however, consider as having *disproved* the view taken in the text. We can no more accept the principle of arbitrary and casual variation and natural selection as a sufficient account, *per se*, of the past and present organic world, than we can receive the Laputan method of composing books (pushed *a l'outrance*) as a sufficient one of Shakspeare and the Principia. Equally in either case, an intelligence, guided by a purpose, must be continually in action to bias the directions of the steps of change—to regulate their amount—to limit their divergence—and to continue them in a definite course. We do not believe that Mr. Darwin means to deny the necessity of such intelligent direction. But it does not, so far as we can see, enter into the formula of his law; and without it we are unable to conceive how the law can have led to the results. On the other hand, we do not mean to deny that such intelligence may act according to a law (that is to say, on a preconceived and definite plan). Such law, stated in words, would be no other than the actual observed law of organic succession; or one more general, taking that form when applied to our own planet, and including all the links of the chain which have disappeared. But the one law is a necessary supplement to the other, and ought, in all logical propriety, to form a part of its enunciation. Granting this, and with some demur as to the genesis of man, we are far from disposed to repudiate the view taken of this mysterious subject in Mr. Darwin's work. (*Note added* Jan. 1861.)

(12.) From METEOROLOGY we learn to refer the great system of aquatic circulation, which transfers the waters of every one region of the ocean, in the course of time, to every other, to the action of our trade-winds, and their compensating currents, the anti-trades; themselves the results of solar action in combination with the earth's rotation on its axis. By the oceanic currents thus arising, the material carried down by rivers, or abraded by the action of the waves (increased in their efficiency by the extent of sloping beach produced by the rise and fall of the tides), is carried off and dispersed abroad, or, it may be, collected by subsidence in deep and comparatively motionless hollows, or in eddy-pools. There are features in the outlines of our continents on the great scale which bear obvious reference to some such process. Thus, the excavation of the Gulf of Mexico and the Caribbean Sea is an evident effect of the continued and powerful action of the gulf stream, or rather of the general set of the great South Atlantic current on that part of the American coast which issues thence at present in the concentrated form of the gulf stream, and which, unless counteracted by other causes, must sooner or later cut through the Isthmus of Darien. In so doing it would leave a chain of islands like those which, on a larger scale, serve to keep up an ideal connection of the continent of Asia with the great mass of Australia. Australia itself may thus be considered as

forming the same sort of southern appendage, past or future, to the eastern part of the great Europo-Asiatic continent which Africa does to its western, and which South America does to North. Looking only at the land in great masses; regarding Africa as South Europe, and Australia as South Asia, we may still form a tolerably general conception of the distribution of land and sea by regarding the land as chiefly collected in the northern hemisphere in a mass which, but for the narrow interval of Behring's Strait (not more than 40 miles across), would be continuous, and which sends down three great lobes into the southern, where they appear as three projecting apexes pointing towards the south pole, which they approach by not very unequal degrees of remoteness, and surround at not very unequal intervals of longitude; much as the thumb and first two fingers of the hand in the attempt to grasp with them a globe of a couple of inches in diameter.

(13.) But although the southern hemisphere, as compared with the northern, is more aquatic, yet, if we would divide the globe into two hemispheres, the one of which shall contain the greatest quantity of land, and the other of water, it must be cut by a plane perpendicular—not to the axis of rotation, but (singularly enough) to the diameter passing through the south-west corner of England. A chart of the two hemispheres projected on

the horizon of this point (or, which comes very nearly to the same thing, on the horizon of London) exhibits the one containing all the great continental masses, except Australia and the small tapering extremity of South America, while, with these exceptions, and those of the great islands of Sumatra, Borneo, and New Guinea the other is nearly all occupied by water. The fact is instructive, as it proves the force by which the continents are sustained to be one of *tumefaction*, inasmuch as it indicates a situation of the centre of gravity of the total mass of the earth somewhat eccentric relatively to that of the general figure of the external surface—the eccentricity lying in the direction of our antipodes; and is therefore a proof of the comparative *lightness* of the materials of the terrestrial hemisphere.

(14.) As regards, then, the general configuration of the land and its distribution over the surface of the globe, in referring it to the causes above indicated, we have done all that is possible in the present state of geological knowledge. It must be accepted as part and parcel of the arbitrary *data* of our subject. Not that speculation has been wanting as to the ultimate origin of that configuration. The globe has been likened to a great crystal, formed by cooling from fusion—its angles and edges cropping out from the general spherical surface —its great mountain chains, and the deep clefts of its sea-valleys to the corrugations on the surface of a molten

mass formed in the act of setting, by crossing systems of crystallization. And more recently* a suggestion has been put forth, attributing the forms of the continents, not to any effect of crystallization, but to the contraction of dimension due to the cooling of a homogeneous fluid nucleus, modified by the resistance of the surface already solidified to a further change of dimension; in a word, to a crumpling or shrivelling of the exterior crust arising from the withdrawal of support from within. It is not easy, however, to see (though the author cited thinks otherwise) how such a cause, acting on a homogeneous spheroid, equably invested in every part, could result in anything other than a further flattening inward of the already flattened polar portions, *i.e.*, in an increase of external ellipticity, or, in other words, in the production of an annular equatorial continent—and to suppose an original difference of resistance (from which, no doubt, undulated forms, both of meridians and parallels might so arise) is only to shift what is arbitrary in the assumption a step farther away; since by properly assuming the law of resistance to flexure, any given form of crumpled surface might arise. Although, then, it is certain that such a cause, acting under any conditions, must produce *some* protuberances, and, under fitting ones, *might* produce those

* "Discours sur la condition Physique de la Terre." Par M. Jean Reynaud.

actually existing, we are still as far from a rational explanation of the *observed* forms on this, as on any other supposition.

(15.) There are, however, local peculiarities in the outlines of the land where the effect of causes now in action is distinctly traceable, as we shall hereafter take occasion to shew when speaking of Deltas, Sand-spits, and some other features of coast-lines, evidently originating in tidal action combined with that of currents, and, in one or two instances (as in the Spit of Arabat) of winds. There are other peculiarities also, of which no such account can be rendered, but which yet, being of frequent occurrence, would seem to point to some general cause, determining the direction of those movements by which the rise of the land from the sea-bed has been effected. We allude to the very evident tendency of the outlines of coasts to run out into peninsular projections, having a meridional direction, or a near approach to such. Not to speak of the three great prolongations of the northern continents into the southern hemisphere, we may instance as cases in point the peninsula of Hindostan, and on a smaller scale those of Cambodia and Carpentaria, the Malayan, Corean, and Kamschatkan peninsulas, and those of California and Florida. Nay, even the more continental masses of Greenland and Scandinavia (including Sweden, Norway, and Lapland) may be cited as coming under this law.

(16.) *Of the Atmosphere.*—We must refer our readers to works on Meteorology, and more especially to an article in the Encyclopædia Britannica on that subject by the author of the present volume, for an account of the nature and constitution of the atmosphere, and the general laws which regulate its movements, and the circulation of heat and moisture operated by them over the surface of the globe. The effects of these movements, in producing the modifications of climate prevailing in different regions, belong, however, to the proper object of this essay, but must be deferred until we have brought the reader acquainted with those features in the arrangement of the land and water upon which these modifications depend. There are, however, one or two points which it is right to mention here, and first, as to the total mass of the atmosphere. It is stated in the article referred to as being one 180,000,000th part of the total mass of the earth. This requires correction; the true proportion is one 1,125,000th. The absolute weight there set down (11⅝ trillions of pounds avoirdupois) is, however, correctly computed. 2dly, We have to regret the omission of all mention in that article of Lieutenant Maury's most valuable and important works,—*The Wind and Current Charts* and *Sailing Directions.* Neither those works, nor his more recent one on the *Physical Geography of the Sea,* had then reached us. Though compelled, as we shall hereafter find

ourselves, to dissent from several of the philosophical views put forward in the last-mentioned work, we do so with the most grateful recognition of the zeal and indefatigable industry he has exhibited in the collection and arrangement of a vast mass of facts, and the ability and success with which he has been able to combine them for practical use. The *Wind Charts*, now in process of publication by the Board of Trade, are founded entirely on the numerical data so collected and arranged, and will exhibit, on simple inspection, the prevalent wind, and its average deviations, both in direction and intensity, for each quarter of the year, in every area of 10° in longitude and latitude over every part of the sea, and in particular regions, where necessary, in closer detail.

OF THE SEA.

(17.) *Extent, Mean Depth, entire Content, and Mass of the Sea.*—From a careful measurement of its extent, as laid down in charts, it has been concluded that the dry land occupies about 49,800,000 square statute miles. This does not include the recently-discovered tracts of land in the vicinity of the Poles, and allowing for yet undiscovered land (which, however, can only exist in small quantity), if we assign 51 millions to the land, there will remain about 146 millions of square miles for the extent of surface occupied by the ocean. Its mean depth cannot, of course, be stated with any certainty.

There are phenomena in the formation and progress of the tide-wave, and of certain other great undulatory movements, which are incompatible with an average *depth under four or five miles. See sec. 80.* Most of the soundings which have been taken far from land, and in deep water, fall, however, far short of these limits; but some have attained the higher of them, and there are numerous instances where 20, 30, 40, and even 50 thousand feet of line run out have failed to give distinct evidence of the bottom having been reached. A *mean* depth of four miles may however be taken as one quite as likely to be beyond the truth as within it; the more so, as a great proportion of the vast area of the Pacific is so abundantly bestrewn with islands as to authorize a reasonable suspicion that its average depth is less than that of the Atlantic, where islands are comparatively rare, and of which the depth has been ascertained over no inconsiderable portion of its whole extent. Calculating on these data, we find for the total cubic contents of the sea, 788 millions of cubic miles, and for its mass or weight (taking the specific gravity of sea-water under a pressure of two miles 1·0151) 3,270,600 billions of tons, or one 1786th part of the total mass of the globe.

(18.) The most remarkable general feature which the sea presents to the physical geographer is its *continuity.* With exception of the Caspian Sea, the little Sea of Aral, and a few other quite trifling salt-water lakes (trifling,

that is, in comparison with the whole amount of water), the ocean is one and undivided, throwing its arms round the globe in such a way as to justify the notion and description of it by the ancient tragedian, "*περι πασαν ειλισσομενος χθον' ακοιμητῳ ῥευματι.*" Even the most closed and the deepest indentations which it makes into the land—the Mediterranean and the Red Sea—have deep water at their entrance, and a sufficient breadth of opening to admit a free communication with the general area.

(19.) *Composition of Sea Water.*—The sea consists wholly of salt water; and it is this continuity of all its parts, conjoined with the system of circulation of its waters in currents, caused by the regular and perpetual action of the winds, which ensures the uniformity, or near approach to uniformity, of its saltness in every part. As the sea continually receives the drainage of all the land, besides having, in the course of countless ages, washed over and over again the disintegrated materials of successive continents, it must of course hold in solution all the saline ingredients capable of being separated and taken up by such lixiviation in cold water; in fact, in greater or less quantity, every soluble substance in nature—such, at least, whose existence in extremely dilute solution are not incompatible. By far the larger proportion, however, consists of chloride of sodium (common salt), after which occur chlorides and sulphates of magnesia and lime in some considerable abundance.

And in much more minute, but yet appretiable quantity, occur salts of potash and ammonia, the iodide and bromide of sodium, carbonate of lime, silica, and other matters too numerous to mention.* The sulphate and carbonate of lime, and the silica, however minute the percentage of the two latter, are yet of vast importance in the economy of animated nature, as furnishing all the lime and silica out of which the shells of Mollusca, the structures of the coral and other similar insects, and the shells and carapaces of the siliceous infusoria, etc., are derived. But besides these saline and earthy ingredients, metallic salts in excessively minute quantity have been shewn to exist in sea-water. Thus, copper is present to such an extent, that clean and polished iron dragged in the wake of a ship, during even a short voyage, has been observed to come up with a film of that metal precipitated on it.† Silver also is found in combination with the old and worn coppering of ships to such amount as to make it worth while to extract it. It has been computed from some analyses of such copper, compared with the total distance run through by the ship, and the time of its remaining attached, that at least two

* While this sheet is passing through our hands we see the discovery of a new alkali (cæsia) in the mineral waters of Kreutznach (and therefore, also, no doubt, in sea water) announced by Messrs. Kirchoff and Bunsen.

† Query, whether iron so dragged in a ship's wake might not take up a portion of the copper dissolved off the ship's bottom.

millions of tons of silver are thus held in solution in the whole ocean.

(20.) The mean specific gravity of sea water taken up at a small depth (a few feet) below the surface (so as to be out of reach of the *immediate* influence of *recent* rain), reduced to 62° Fahr., may be stated at 1·0275, which experiment shews to correspond to a *total* percentage of saline contents, irrespective of the difference of the ingredients, of about 3·505, so that it is incorrect to state, as some have done, that the saline contents do not add to the bulk. This of course is to be understood of water taken up in open sea, out of reach of the influence of rivers, icebergs, etc., which produce local variations, to which we shall presently recur. Beyond such influences, however, there are meteorological causes in action which produce a perceptible deviation, dependent on geographical situation, from the exact average. Thus, in those portions of the ocean, on either side of the equator, swept by the trade-winds, especially towards their northern and southern limits, the saltness of the surface water may be expected to be, and is in fact found, somewhat in excess of what prevails either on the equator on the one hand, or beyond the tropics on the other. For these winds arrive from higher latitudes deficient both in heat and moisture (METEOROLOGY, Encyclopædia Britannica, art. 111), and take up both in their progress towards the equator, while they return little or

none of the fresh water so taken up, in the form of rain, till their arrival at and near the equator itself. There, however, they at once precipitate a large proportion of the water so absorbed, a process which, being in constant operation, must in some degree freshen the surface. Thus, Captain King, in his South American Survey in 1829-30, found the maxima of specific gravity in the Atlantic to occur in latitudes 27° N. and 20° S., the mean result for both being 1·02808 at 62° F., while in the equatorial region, from 5° N. to 5° S., the mean of his results is only 1·02723. Ruschenberger and Porter, as reported by Maury, found the Atlantic maxima in 17° N. and 17° S., and in 20° N. and 17° S., respectively. The mean of all gives 18° N. and S. So also, in the Pacific, Captain Beechy, in his survey of Behring's Straits in the Blossom (1825-8), found the maxima to occur in latitudes 22° N. and 20° S., their mean being 1·02937 (reduced to 62°),* that of the equatorial zone being 1·02791. On the other hand, beyond these limits in the ultra-tropical regions, where the anti-trade winds prevail, the whole of their residual moisture is discharged in rain or snow, while at the same time, owing to the habitually lower temperature of these regions, evaporation from the sea-surface is very much diminished. And, accordingly, the results of both King and Beechy indicate a slight

* Captain Beechy's results (where reduced by him) are given for 60°, and are corrected by—0·00020 to bring them to 62°.

though very perceptible progressive diminution of specific gravity in proceeding towards either pole—the mean of Captain Beechy's results between 55° and 60° of both north and south latitudes in the Pacific giving 1·02580, and those of Captain King, in the corresponding region of the South Atlantic, 1·02551—results on the whole in excellent accordance with each other, and which leave no room for doubt as to the general fact in question.

(21.) At the mouths of great rivers the sea is often superficially freshened to a considerable distance from shore. This is the case with the Amazon River to such an extent, that fresh water may be taken up from the sea surface when out of sight of land, and the sea itself is rendered sensibly less saline at two or three hundred miles from its mouth. At the time of the inundations of the Nile also, the water is perceptibly freshened out of sight of land.

(22.) In the Euxine, and still more in the Sea of Azof, the supply of fresh water, from the rivers feeding them, is greater than their waste by evaporation, and their communication with the Mediterranean being restricted by the long and narrow channels of the Bosphorus and the Dardanelles, out of which a current always sets in calm weather, they have become materially fresher than the general average. The Euxine water has a specific gravity of 1·01410; and the Sea of Azof, which is shal-

low, and of small extent, and receives a considerable river (the Don), probably less. So also in the Baltic, which is a shallow sea communicating with the main ocean by a shallow and obstructed channel, the specific gravity varies from 1·00476 at Tunaberg, to 1·020437 off the Scaw Point, at the entrance of the Cattegat—[Thomson].

(23.) With respect to the Mediterranean, it has been held, on the authority of Halley, that its evaporation is materially greater than the extra supply from its rivers, and that, therefore, it must be increasing in saltness by the continual indraught of sea water from the Atlantic, unless relieved (as has also been supposed) by an under-current of salter and heavier water flowing outwards. This opinion has recently been called in question by an authority entitled to every respect; but from the best consideration we have been able to give the subject, we feel compelled to acquiesce in Halley's conclusion. A few words will suffice to explain the grounds of our conviction on this point. The total area of the Mediterranean, Euxine, and Azof seas, amounts to 1,150,000 square miles, and may be regarded nearly enough for the purpose of such a calculation, as traversed medially by the isotherm of 68°. Now, this is the mean temperature of July at Tottenham, at which, for that month, the observations of Howard assign an average evaporation of 4·111 inches, which, continued over the year, would

give 49·33 inches. Dalton's determination for Liverpool for the same month is 5·11 in., corresponding to 61·33 in. per annum. The observed annual evaporation at Marseilles exceeds 85 Paris inches (*Kämtz*, i. 446). So that we shall be quite within limits in taking 50 inches per annum as the average evaporation over the whole surface in question. As regards the quantity restored by rain, Palermo,* as an insular station, well situated about the middle breadth of the Mediterranean, gives 22·3 in. for the fall of rain, which may be taken as the average supply from that source, leaving 27·7 in., or in round numbers, 28 in. for the excess of evaporation. This, computed as extending over the whole area, gives 508 cubic miles of fresh water annually abstracted.

(24.) The Nile delivers into the sea 101,000 cubic feet of water per second (Talabot) on the average of the whole year, which gives an annual contribution of fresh water from this river alone = 21·653 cubic miles. So that, even on the extravagant supposition that each of the other principal rivers (the Danube, Dnieper, Don, Rhone, Dniester, Ebro, and Po) contribute as much as the Nile, we should still have only 173 cubic miles of river supply, leaving 335 to be furnished from the Atlantic.

(25.) In point of fact, the current which sets in at the

* A mean of eleven stations at points surrounding the whole of the Mediterranean, as reported by Admiral Smyth, gives 23·05 inches.

Straits (estimated by Admiral Smyth* as 4 miles in breadth, with an average velocity of 2½ miles per hour) would carry in, supposing it to extend 30 fathoms only in depth, 2986 cubic miles per annum, of which it is therefore past a doubt that at least 2000 must flow out again in the form of an under-current (no regular lateral return currents being observed to exist). This enormous interchange of water is sufficient perfectly to account for the observed fact that the Mediterranean is not sensibly salter than the ocean, and not materially so at great depths than at the surface, though, on arranging the results recorded by the last-named eminent hydrographer in groups according to depth, a very perceptible increase *is* apparent. Thus we find (setting apart the last result as anomalous, and as a case in which, by bare possibility, a submarine brine spring may have been struck upon)—

At depths from	Specific Gravity.	By
0 to 8 fathoms	1·0271	2 observations.
34 „ 60 „	1·0285	4 „
250 „ 450 „	1·0297	3 „
670 „	1·1288 ??	1 „

(26.) The disproportion between evaporation and fresh-water supply is carried to its maximum in the Red Sea, where rain scarcely ever falls, into which no rivers run, and throughout whose whole extent an excessive temperature always prevails. The evaporation has been

* Mediterranean, p. 160.

computed at 165 cubic miles per annum, so that but for an interchange of water with the Persian Gulf, similar to that which takes place between the Mediterranean and the Atlantic, only more intense, it could not fail to be speedily reduced to the condition of an almost saturated brine.

(27.) In several places in the Mediterranean, springs of fresh water, nay, even subterraneous rivers, well up to the surface from considerable depths. Many such are enumerated by Admiral Smyth; but the most remarkable is Anàvolo, in the Sinus Argolicus, between Kiveri and Astros, where a body of fresh water fifty feet in diameter rises with such force at a quarter of a mile from the shore, as to produce a visible convexity of surface, and to disturb the sea for several hundred feet round.—(Leake, *Travels in the Morea*, ii. 480). In the Gulf of Xagua, south-west of the Port of Batabano, on the south coast of Cuba, a similar instance occurs (Humboldt, *Aspects*, p. 233), and others are said to exist in the Pacific, among the Sandwich Islands.

(28.) In the Polar Seas, too, there are extensive regions where large accretions of fresh ice, from snow or glaciers melting in summer, render the surface-water comparatively fresh. But these are too obvious exceptions to the general fact to need more than a passing notice.

(29.) The following is given by M. Regnault (*Chim.* ii. 193) as a mean result of the analysis of sea water.

Under the head of "loss" may be comprised the various ingredients which exist in too small quantity for distinct separation, except in operations conducted on a very large scale.

Water		96·470
Saline ingredients = 3.505.	Chloride of Sodium	2·700
	" Magnesium	0·360
	" Potassium	0·070
	Sulphate of Lime	0·140
	" Magnesia	0·230
	Carbonate of Lime	0·003
	Bromide of Magnesium	0·002
Loss (including Iodides, Silica, etc.)		0·025
		100·000

(30.) *Colour and Phosphorescence of the Sea.*—The sea is only purely blue in the open ocean, or in very deep water, out of the fouling influence of rivers, the washing of coasts, or such currents as drift along mud and impurities. When clear of all such causes of discoloration, a white object, as a plate thrown overboard, is seen to become bluer and bluer as it sinks. The light illuminating the Grotto of Capri, in the bay of Naples, which is mainly derived from reflexion at the bottom of the water, and which has traversed many yards of sea-water, is very blue. This colour is common to the sea and to lakes of pure fresh water. In the little lake of Chede (now filled up by the fall of a mountain), the blue colour of the water used to be very apparent at a few yards in depth. So also of the water in the Grotto of Vaucluse.

It will hardly be contended that in these instances the colour is owing either to salt, which is insisted on by some as the cause of the colour of the ocean, or by cuprate of ammonia, which, on the strength of the discovery of copper in sea water, has recently been suggested. The intense blue colour of the Rhone, where it issues from the Lake of Geneva (far surpassing that of the bluest sea), is alone sufficient to negative both these explanations. Like the blue colour of the sky, the explanation is yet to seek, unless we are content with the very simple, but somewhat doubtful one, that in both cases it is an absorptive colour proper to either element.

(31.) In this view of the subject, wherever the sea is otherwise than fully and purely blue, we may be sure it is by reason of *solid* matter held in *suspension*. In many instances this is obviously the case. The surface water both in the Indian and Pacific Oceans is frequently coloured in patches as far as the eye can reach, of red, brown, or white, the water of which, when taken up and carefully examined, is found to be full of animalculæ of the colours in question. On the shores of the Red Sea a red matter is thrown up, which Ehrenberg has found to be of vegetable origin. Along the coast of China and especially in the Yellow Sea, spots of that colour are said to be not unfrequent. Captain Kingman, in lat. 8° 46′ S., long. 105° 30′ E., passed through a tract of water 23 miles in breadth and of

unknown length, so full of minute (and some not very minute) phosphorescent animal organisms, as to present the aspect (at night) of a boundless plain covered with snow. Some of these animals were "serpents" of six inches in length, of transparent gelatinous consistency, and very luminous. Such tracts by daylight appear white, not by reason of light emitted from the insects, but of the sun's light reflected by their filmy and all but aqueous substance. (*Conf.* Buist, *Naut. Mag.* 1854.)

(32.) *The Phosphorescence of the Ocean* is a phenomenon which strikes all who witness it with wonder and admiration. It prevails largely through the whole extent of the tropical seas, and proceeds from a great variety of marine organisms—some soft and gelatinous, some minute crustacea, etc., of the genera Cancer and others. They mostly shine when excited by a blow, or by agitation of the water, as when a fish darts along, or oar dashes, or in the wake of a ship as the water closes on its track. In the latter case are often seen what appear to be large lamps of light rising from under the keel, and floating out to the surface, apparently of many inches in diameter. These we have never succeeded in catching, though we feel assured to have seen them enter the net (of Urling's patent lace) dragged along for them, so that the light must have emanated from a creature small enough to escape through the meshes. One of the most remarkable of these luminous creatures

is a species of pyrosoma, a tough cartilaginous bag or muff-shaped body, of more than an inch in length, which, when thrown down on deck, bursts into a glow so strong as to appear like a lump of white hot iron.

(33.) One of the most curious phases of phosphorescence which we have witnessed (and which we have not met with elsewhere described) is the appearance on the surface of calm or but little agitated water, of luminous spaces of several square feet in area, *shining fitfully, and bounded by rectilinear, or nearly rectilinear, outlines*, presenting angular forms, across which the light flashes as if propagated rapidly along the surface.*

(34.) *Depth and Form of the Bottom of the Sea.*—Of the *average* depth of the ocean we have already spoken. Of particular districts in the great ocean, nothing very distinct can be stated, except in respect of the North Atlantic, or the Atlantic basin, in which soundings enough have been obtained to enable something like a rude chart of level lines to be constructed, and of which a summary account may be stated as follows. We shall suppose level lines corresponding to depths of 1000, 2000, 3000, 4000, and 5000 fathoms to be laid down, which will therefore trace out what would be the coast

* [This must not be confounded with an apparently oily, phosphorescent film, which floats on the surface in harbours, etc., and originates probably in the decomposition of fish or other animal matter. The phosphorescence of a decaying lobster is athing of very ordinary remark, but perhaps may be due to minute living organisms.]

lines of continents and islands, were the sea to sink in level, successively by these several quantities. The first of these lines (that of 1000 fathoms) corresponds pretty closely in its general form with the existing coast line, or rather with what that coast line would be, supposing on the American side the Caribbean Sea and the Gulf of Mexico filled in, so as to carry the continent out to the extreme verge of the Bahamas and Caribbee Islands; and supposing the irregularities of the North American coast smoothed off by carrying out the coast line clear round Nova Scotia, to include Newfoundland with the Great Bank; and supposing, on the European and African side, the Bay of Biscay and the British and Irish Channels also filled in. From the coast lines so arising, the first level line in question hardly anywhere deviates more than 120 geographical miles (60 to the degree). Nor does it appear that the sea line so altered would give rise to any considerable new masses of land, but only a very moderate extension of the Azores, and a very trifling one of Madeira, the Canaries, and the Cape Verde Islands.

(35.) The level line of 2000 fathoms along the east coast also conforms very nearly to the outline of the European and African continents, taking in the Canary and Cape Verde Islands, never departing more than about 250 geographical miles from the present coast, except in the case of the last-named islands, but clinging closer to it

along the European than the African coast. On the western side this level line, from 10° of south latitude northwards, accompanies the coast (modified as above) for the most part considerably within the same limit of distance as on the eastern (the descent being most precipitous at the edge of the Caribbean Sea), until we reach a point about lat. 43° N., long. 43° W.,* where it quits the neighbourhood of the existing coasts, and suddenly turns southwards, running in a meridional direction for 16° of latitude, and forming so much of the western boundary of a great submarine table-land which fills nearly the whole bed of the northern part of the Atlantic basin, and of which, if laid dry, the peak of the Azores would be the culminating point. Were that the case, we should see a lobe of land (following, singularly enough, the general tendency of configuration pointed out in art. 15), not very unlike Italy in form, extending southward to the tropic of Cancer, leaving a channel of sea of about 500 miles broad, between it and the eastern continent, and connected at its south-western extremity with a great triangular mass, like Sicily in shape; two sides of the triangle having a general conformity to the present outline of the American continents, so as to leave a channel of about 800 or 900 miles in breadth on that side, separating it from the coast of the United States.

(36.) It is this sub-marine continent or plateau which,

* All our longitudes reckon from Greenwich.

happily for the communication between the old and new world; appears as if provided to receive the lines of telegraphic wire which will one day bring America into intellectual contact with Europe.* From Cape Race, in Newfoundland, to Cape Clear, in Ireland, it has been ascertained to form a continuous platform of nearly 400 miles in breadth, at the depth of about 2000 fathoms, which has been sounded and surveyed for that purpose. Its surface is covered with broken shells of foraminated and diatomic organisms, among which the cable might find secure lodgement, and in all probability become ultimately incrusted and imbedded in their mass.

(37.) Were the Atlantic to sink another thousand fathoms (to the 3000 fathoms level line), the whole of the European and African side of its bed would be laid dry. The table-land spoken of would form an extension of the European continent. The British Islands, and the north of Europe, would become united with the Labrador coast, and nothing would remain of the ocean but a comparatively narrow channel, following at no great distance the present line of the American continent—reduced to very slender dimensions at the Caribbees, and thence opening out into a bay or great salt lake, occupying that part of the area opposite the United States, and extending between Bermuda and the southern edge of the Bank of Newfoundland. The central and deepest

* The thing is done! (Aug. 1858.)

part of this lake would seem to be a long valley running nearly east and west from about 46° to 67° west longitude, along which a depth of from 25,000 to 30,000 feet at present exists.

(38.) By the first step in the subsidence of the ocean we have been supposing, the Baltic would be laid dry —its depth nowhere exceeding 1100 feet—as would also the German Ocean, the British and Irish Channels, and the Bay of Biscay; but the Mediterranean would remain as a great salt lake, a bar extending across the Gut of Gibraltar, at about 900 feet in depth, inside of which the water deepens so rapidly, that between Gibraltar and Ceuta, where the breadth of the channel does not exceed 12 miles, the depth is already 6000 feet; 90 miles east of Malta, we find a depth of 15,000; between Rhodes and Alexandria, 9900; and between the latter place and Candia, 10,200; so that the next step in our ideal descent of the general sea level would lay the whole bed of the Mediterranean dry. We see then, that the Mediterranean fills an immensely deep and comparatively a precipitous chasm, which would almost seem to have been the effect of subsidence towards the south, contemporaneous with and complementary to the upheaval of the great line of mountainous tracts which run along the whole extent of south Europe.

(39.) The depth of the Arctic Ocean is probably not great. From Baron Wrangel's explorations we learn that

over very extensive tracts of the northern coast of East Siberia the water shoals so gradually, that at upwards of 150 miles from land the depth is only fourteen or fifteen fathoms, and the broken character of the northern coast of America, with its labyrinth of islands, and tortuous channels, affords a similar indication. In the axis of Baffin's Bay, however, a few days' sail from Finskernaes, in Greenland, Dr. Kane found 1900 fathoms.

(40.) Of the Pacific, too little is known to afford any ground for forming even the most general notion of the form of the level lines of its bottom. The islands scattered over it spring up, for the most part, from very deep water, and soundings are said to have been obtained of enormous depth, even greater than five miles. The deepest recorded by Maury was obtained by Lieutenant Brooke (with a deep-sea sounding apparatus of peculiar and simple construction, *bringing up specimens of the bottom*), is 58° 46′ N., 168° 18′ E., being 2700 fathoms. The greater interest therefore attaches to an estimate of its average depth in the section across its whole breadth from Simoda, in Japan, to San Francisco, in California, along the parallel of 34° N. latitude, derived by Professor Bache (*Report of Superintendent of the U. S. Coast Survey*, 1855, p. 346), from observations which can certainly be depended upon of the time taken to traverse it by the great waves of December 23, 1854, caused by the terrible earthquake

which ravaged Japan on that day. Several of these waves were propagated all across the Pacific, and were recorded on the self-registering tide gauges of San Diego and San Francisco, on the California coast. A comparison of the observed times of arrival so recorded, with the times at which the waves took place in Japan, leads to the conclusion that a wave 217 miles in breadth can be propagated across the interval in question (4527 miles) at an average rate of $6^{m}\cdot 1$ per minute, from which, by the theory of waves, Professor Bache concludes a mean depth of 2365 fathoms, or 14,190 feet.

(41.) In the "Coral Sea," 13 S., 162 E., a depth of 2150 fathoms, with a specimen of the bottom, was obtained by Lieutenant Brooke. The same ingenious officer reports a sounding of 7040 fathoms in the Indian Ocean (42,240 feet, or exactly eight miles!), but under circumstances authorizing considerable doubt as to the correctness of the result. It deserves remark, that off the mouth of the Hoogly river, in the Bay of Bengal, there exists a sudden and deep depression in the ocean bed, called "The Bottomless Pit," an epithet, however, relative only to the ordinary "deep-sea lines" of the old merchant vessels, yet of importance as occurring just where the lighter part of the sediment of the Ganges is carried out to sea, and for which it serves as a receptacle.

(42). Among the most interesting results of the mode of sounding adopted by Lieutenant Brooke, may be

considered the evidence procured by it of the nature of the deposits in actual process of formation in the tranquil depths of the ocean, from a microscopic examination of the specimens procured. Thus, the specimens brought up in the Coral Sea are found to consist chiefly of the siliceous spiculæ of sponges, with a few other siliceous and some calcareous infusorial shells; while over the basin of the North Atlantic, over the whole extent of the telegraph plateau, and the wide area covered by the expansion of the Gulf Stream, the bottom appears to consist exclusively of the remains of delicate calcareous exuviæ of animalcules of the foraminiferous family, in a state of such perfect preservation as proves them to have suffered no abrasion, but to have been quietly deposited, on the death of the animals, from the surface water which served them for a habitat during life. Thus we see here going on the formation of a cretaceous deposit exactly analogous to our own chalk formations, which the researches of Ehrenberg and others have also found to consist almost exclusively of the shells, and fragments of shells, of minute infusoriæ. In some places, too, volcanic ashes and pumice, in fine powder, are found—the product, doubtless, of wind-drifted ashes bestrewing the surface.

(43.) *Subdivisions of the Sea.*—The ocean separates the globe into two principal continental masses, which our insular position between them entitles us to designate as

the Eastern and Western Continents. They are separated on one side by the Atlantic Ocean, which extends north and south, in all probability, from pole to pole, and which is continued across the north pole, and through the Arctic Ocean or north polar basin, from which it is hardly separated by any well-defined line of demarcation, the interval between the Greenland coast and that of Norway alone being nearly 500 miles; not to speak of the channel communications leading out of Davis' Strait—while to and probably over the south pole it presents nothing but open sea. The separation of the continents on the other side is effected by the Pacific Ocean, which, but for the narrow communication with the Arctic Sea by Behring's Strait, would come to be considered as a great bay, bounded on the eastern side by the whole coast line of North and South America, and on the western by that of Asia, considered as prolonged by a chain of great islands to the Australian continent. Narrow and shallow as this channel of communication is—not exceeding 30 miles in breadth where narrowest, and 25 fathoms in its deepest channel—it is yet important in the economy of nature, inasmuch as it allows a portion of the circulating water from a warmer region to find its way into the polar basin, aiding thereby not only to mitigate the extreme rigour of the polar cold, but to prevent, in all probability, a continual accretion of ice, which else might rise to a mountainous

height. Nothing, indeed, can be more remarkable than the way in which all direct equatorial circulation is barred by the Isthmuses of Darien and Suez on the one hand, while on the other the polar communication is left free. One of the reasons adduced in support of the early, but erroneous, opinion that the figure of the earth is that of an oblong spheroid, was drawn from a crude notion of the continued accumulation of ice and snow over the polar regions, which it was argued must result in an indefinite prolongation of the earth's polar axis. The actual form of the continent, however, prevents any such consequence from taking place, and it is probable that the melting of the ice where it rests on the sea, together with the bodily drifting away of detached masses, form, in the long average, a compensation to the effect of continued precipitation from the atmosphere.*

(44.) Another such vast bay or gulf, but without any northern outlet (the Red Sea and the Persian Gulf being barred), is the Indian Ocean, limited westwards by the African and Arabian coasts, northwards by the south coast of Asia—the peninsula of Hindostan breaking it into

* On land, the penetration of the central, or volcanic, and local heat of the globe may assist in limiting its increase. Dr. Kane describes the [illegible] in lat. [illegible] N., as issuing in a roaring and [illegible] of ½ mile broad, from beneath a glacier. [illegible] (78° 17′ N.) is fed by a glacier stream, never [illegible] summer or winter.

two deep and nearly symmetrical indentations—and eastwards by the broken masses of Sumatra, Java, and the Indian Archipelago, and by the west coast of Australia.

(45.) Each of these great bodies of water communicates without any natural barrier-line with the Southern Ocean, which probably extends across the pole beneath the great icy barrier discovered by Sir James Ross. If, therefore, we would distinguish between them, we must assume arbitrary lines of demarcation. On the north, the arctic circle, which passes within a degree of the narrowest part of Behring's Strait, forms a very appropriate limit to the "Arctic Ocean." The Antarctic Ocean has no such natural limit, but under the wider designation of the "Southern Ocean" may be taken to embrace all the area limited by great circles drawn between Cape Hoorn, the Cape of Good Hope, and Bass Strait, so as to constitute these localities the southern termini of the Atlantic, Pacific, and Indian Oceans. This appears a simpler division than that which runs meridians up from the three capes (the two last named and Cape Pillar) to the Antarctic Circle, so as to form a purely imaginary Antarctic Ocean, and to constitute a Southern Ocean, equally imaginary as to its limits, between the Indian and Antarctic.

(46.) Each of the three principal oceans has subordinate seas, specially marked out by distinguishing features. Besides the Mediterranean and the Baltic, on the Euro-

pean side, the Atlantic opens out, on the American, into the great bays which bear the names of Baffin and Hudson, both heavily encumbered with ice; the former of which communicates by a labyrinth of intricate and ice-obstructed passages with the Polar Sea, and is the source from whence are continually drifting southwards those floating icebergs which form one of the chief dangers of Atlantic navigation. On the other hand, the deep indentation of the Gulf of Mexico and the Caribbean Sea, nearly land-locked by the peninsula of Florida and the long chain of the West India Islands, forms a basin of hot water, having a higher mean temperature than any other oceanic district of equal extent.

(47.) The mass of islands which sketches out the connection between the Asiatic and Australian continents, is continued northward along the west coast of the Pacific, forming a loose and broken barrier between the main ocean and the east coast of Asia, and breaking it up into compartments more or less land-locked by them, and by the singular system of meridional peninsulas (of Kamtschatka, Corea, Cambodia, and Malaya) known as the seas of Ochotsk and Japan, the Yellow Sea, and the China Sea. The difference in character in this respect between the western coasts in the two oceans is extremely remarkable.

(48.) On the other hand, their eastern coasts are both characterized by an equally striking absence of features

of this nature. With exception of the Gulf of California, there is no approach to any deep and extensive land-locked indentation along the whole line of western America, nor does any exist on that of west Africa, or along the European coast from the Gut of Gibraltar to the British Channel.

(49.) *Temperature of the Sea.*—The mean temperature of the sea surface, when undisturbed by currents transferring water from a hotter to a colder zone, or *vice versa*, is of course nearly that of the air above it; but on descending below the surface, a most remarkable law prevails. In very deep water all over the globe a uniform temperature of 39° Fahr. is found to prevail, while above the level when that temperature is first reached, the ocean may be considered as divided into three great regions or zones—an equatorial and two polar. In the former of these, warmer, in the latter colder, water is found at the surface. The lines of demarcation are of course the two isotherms of 39° mean annual temperature. The depth at which this temperature is found is about 7200 feet at the equator, and 4500 in the highest accessible latitudes. The medial line of maximum surface temperature is far from following the exact line of the equator, being deflected by the effect of currents, and in the case of the Indian Ocean by the proximity of heated land, as the following tabulated trace of its course, indicating its greatest deviations from, and

intersections with, or near approach to the equator, will shew for each of the three great oceanic regions.

Atlantic.			Pacific.			Indian Ocean.		
Longitude.	Latitude.	Temperature.	Longitude.	Latitude.	Temperature.	Longitude.	Latitude.	Temperature
Deg.	Deg.		Deg.	Deg.		Deg.	Deg	
9 E.	0	80	82 W.	2 N.	84·7	120 E.	8 S.	84·6
0	1 N.	...	97 W.	7 N.	...	104 E.	0	85
46 W.	3 N.	82·6	135 W.	2 N.	81·7	90 E.	9 N.	86
60 W.	10 N.	84	152 W.	0	83·1	68 E.	10 N.	86
84 W.	20 N.	83	180	7 S.	84·7	45 E	12 N.	86
90 W.	28 N.	88*	140 E.	0 +	..			
			130 E.	0	...			
			125 E.	8°S.	84·7			

(50.) Universally, the temperature of the sea surface, for the reasons explained in METEOROLOGY, is far less variable than on land, and there exist vast regions (as may be seen on inspection of the above table) over which an almost absolute uniformity in this respect prevails. The frequent determination of the mean temperature of these regions *to the extreme of precision*, is a practical problem of the highest importance.

(51.) *Currents of the Ocean.*—Every wind that sweeps the ocean drives along before it the surface water. The impulse given is horizontal, and proportional to, or at least increasing in some ratio of, the *relative* motion of the air; a ratio probably higher than that of the simple difference of absolute motions, by reason of the universal

* In the Gulf of Mexico, off New Orleans. It is evident that this is an exceptional result.

roughness of surface consequent on the action of the wind. If the difference of motion be due to an excess of diurnal rotation on the part of the sea, it is the water which (driven against the air) gives out momentum to the latter; if that of the air be in excess, it receives it from that element. In either case, the effect is the same; the two are brought nearer to a community of direction and velocity by their mutual friction.

(52.) The trade-winds occupy two belts on the earth's surface on either side of the equator, which are limited on the equatorial side by a belt of calm air (the movement of which is upward, and in which no prevailing tendency east or west is perceivable). On the polar they are limited by two belts of comparative calm, with uncertain and variable winds, which for our present purpose we may consider as nearly coincident with the tropics. Over the belt of equatorial calms, the N.E. and S.E. trades, *reduced to meridional directions by the eastward frictional impulse of the earth's rotation* (Basil Hall, *Fragments of Voyages and Travels*, 3d Series, i. 162), meet, and to a certain small extent perhaps commingle, in their upward movement; which, however, can only be the case with those portions of air which actually attain the medial line, or approach very near it: for, as the region of calms extends to four or five degrees on either side of that line, the greater part by far of either indraught will rise on its own side, and must

of necessity be turned over towards the pole of its own denomination, and return, as an upper current, by a tract precisely the reverse of that of its arrival.* On the other hand, over the region of tropical calms, a portion of the descending air of the upper current, where it first strikes the earth, is dragged back into the tropical circulation, while the rest goes forward to form the Antitrades (or S.W. and N.W. winds) of the temperate and polar zones, which, as prevalent winds, with more or less frequent *interruptions*, according to local circumstances, occupy both the extra-tropical regions.

(53.) In obedience to the trade-winds, a drift of the intertropical surface water is produced, which tends to carry it in a S.W. and N.W. direction respectively, *towards the equator*, where the meridional components of the two drifts neutralize each other, and their westerly components conspire to produce an equatorial current setting westwards, the borders of which will be stronger than the medial line, because the exciting

* Such at least, is the ordinary, and, as appears to us, the correct dynamical view of the subject, and this is one of the points on which we have the misfortune to differ from Lieutenant Maury, who conceives that the south-east and north-east trades cross as they near the equator, and pursue their course in the upper regions of the atmosphere towards the poles of *contrary* denominations. The point is irrelevant to the matter actually in hand, but it will be necessary to recur to it when we come to speak of the distribution of moisture. [Of course we do not mean to deny the occasional and casual transfer of masses of air from hemisphere to hemisphere by wind gusts crossing the medial line.]

cause is there most energetic. The general current resulting from the concentration of the drift will therefore bifurcate where it meets or nears the land, the northern portion turning northward, and the southern southward.

(54.) In the Atlantic, this bifurcation takes place somewhat south of the equator, off Cape St. Roque. The equatorial current is there not very powerful; but in its progress along the north-east coast of South America, it is reinforced by the whole amount of S.W. drift setting towards that shore from the North Atlantic, and is thereby forced into the Caribbean Sea and through the Channel of Yucatan; and having made the circuit of the Gulf of Mexico, issues through the Straits of Florida; clinging in shore round Cape Florida, whence it issues as the Gulf Stream in a majestic current upwards of 30 miles broad, 2200 feet deep, with an average velocity of four miles an hour, and a temperature of 86° Fahr. It is to the continual scouring of this recess, by so vast a torrent of perfectly pure water from the main ocean, that the extreme and crystalline transparency and intensely blue colour of the Caribbean Sea is owing—a transparency such as to allow every object at the bottom to be clearly seen in 30 fathom water.

(55.) From its issue through the "Narrows" off Cape Florida it is darted off into the main ocean, where it takes up a course (as Lieut. Maury has well pointed out)

conformable (in a general way) to the easterly impulse given by its excess of diurnal rotation, in passing from a lower to a higher latitude, and which drives it away from the American coast in an almost direct N.E. direction *towards* the opening of the Arctic Sea, between Spitzbergen and Norway. Arriving in colder water, it becomes relatively buoyant, and thins off in depth (which has been, by a strange perversion of language, called "running up hill"), spreading itself gradually in width, until its motion at length, conspiring with that of the south-west Antitrades of the extra-tropical latitudes, it is swept on, partly by what may yet remain of its original impulse, but mainly by their aid, as a drift-current (*Stark*) of moderately warm water (51°), into the North Sea. There can be little doubt that a portion of this warm stream enters the Arctic Ocean, and, sweeping round its basin, reissues in the form of a cold current between Spitzbergen and Greenland; after skirting the coast of which latter, it unites with a similar current, also running southward, through Baffin's Bay (and which probably conveys the whole of the water entering at Behring's Strait), and forms a cold stream, which descends along the Labrador coast, and that of the United States, till it becomes extinct, or re-enters the circulation at the point where the Gulf Stream quits the coast.

(56.) It is about the 42d or 43d parallel of N. lati-

tude that this process of thinning off and superficial extension may be said to have *dispersed, and, in fact, destroyed, the Gulf Stream as such*, since at this point, or rather over this region, a large portion of its water, strongly marked by excess of temperature (79°-73°), curves round to the eastward, and is then again deflected southward, forming an eddy or return current, which follows the bend of the great northern protuberance of Africa, but at some distance from the coast, till it again rejoins the equatorial waters. In the interior of this vast circuit, about the tropic of Cancer, and forming a floating island of an elongated oval form, between the 20th and 65th degree of W. long., and the 18th and 28th of N. lat., occurs that extraordinary accumulation of rootless sea-weed, known as the gulf-weed, or Sargasso, consisting almost entirely of the *Fucus natans* *Macrocystis pyrifera*, and affording a home to myriads of molluscs and crustacea.

(57.) The dynamics of the Gulf Stream have of late, in the work of Lieut. Maury already mentioned, been made a subject of much (we cannot but think misplaced) wonder, as if there could be any possible ground for doubting that it owes its origin *entirely* to the trade-winds. A few words on this point, therefore, will not be superfluous. *First*, then, if there were no atmosphere, there would be no Gulf Stream, or any other considerable oceanic current (as distinguished from a mere

surface drift) whatever. By the action of the sun's rays, the *surface* of the ocean becomes *most* heated, and the heated water will, therefore, neither directly tend to *ascend* (which it could not do without leaving the sea) nor to *descend*, which it cannot do, being rendered buoyant, nor to move laterally, no lateral impulse being given, and which it could only do by reason of a general declivity of surface—the dilated portion occupying a higher level. Let us see what this declivity would amount to. The equatorial surface-water has a temperature of 84°. At 7200 feet depth the temperature is 39°, the level of which temperature rises (art. 49) to the surface in lat. 56. Taking the dilatability of sea-water the same as that of fresh, a uniformly progressive increase of temperature, from 39° to 84° Fahr., would dilate a column of 7200 feet by 10 feet,* to which height, therefore, above the spheroid of equilibrium (or above the sea-level in lat. 56°), the equatorial surface is actually raised by this dilatation. An arc of 56° on the earth's surface measures 3360 geographical miles, so that we have a slope of one 28th of an inch per geographical mile, or one 32d of an inch per statute mile for the water so raised to run down. As the accelerating force, corresponding to such a slope (of one-tenth of a second 0·1″), is less than one two-millionth part of gravity, we may

* 9·971 feet, calculating on Dr. Young's formula for the dilatation of water. Lect. ii. 392.

dismiss this, as a cause capable of creating only a very trifling surface drift, and not worth considering, even were it in the proper direction to form, by concentration, a current from east to west; *which it would not be, but the very reverse.*

(58.) *Secondly.*—Whatever the difference of equatorial and polar temperatures in the surface-water, or, were there no difference at all, the actually existing trade-winds must of necessity act on the surface-water in the manner described in art. 51. Their action is in the nature of a *vera causa* which cannot be ignored or set aside. The easterly momentum communicated to *the whole mass of air constituting the trade-wind has,* on its arrival on the equator, been abstracted from the surface-water. The surface water *has* lost that easterly momentum, which is equivalent to saying that it *has* acquired an equal westerly amount, relatively to the dry land. It is for those who deny or under-rate the power of the winds to produce currents to dispose of this momentum otherwise.

(59.) *3dly and lastly.*—Sea water by evaporation, acquires additional saltness and density, and by dilution with rain, the reverse qualities. In this fact we have a *vera causa,* though a very feeble one, for the production of an indraft on both sides *towards the lines of maximum evaporation and minimum precipitation.* These lines (as we have seen, art. 20) are not very remote

from the tropics, being somewhat nearer the equator, it is true, but not so much so as to make it worth while to distinguish them for our present purpose. The diurnal rotation, then, will modify the directions of this indraft. Water coming in to the northern tropic for instance, from the north side, will arrive in a south-westerly direction, and from the south in a north-easterly. The indrawn waters, then, will meet from opposite sides point blank on the tropic, and destroy each other's impulse.* They will simply replace the volume of evaporated water while the denser water subsides vertically. The rain, moreover, which descends on the equator, has, on its arrival at the sea level, no tendency either eastward or westward. It opposes no resistance to being swept in the latter direction by the wind, and thus carried into the general circulation, as part of the equatorial current.

(60.) We ought here to observe, too, that it is by no means necessary, in accounting for the Gulf Stream or other ocean current, to assume or prove the existence of what is called "a head of water." Such currents do not of necessity run from a higher to a lower level. Indeed, such a condition (as a general one) is incompatible with the notion of *circulation*. A circulation in a closed area, produced by an impulse acting horizontally on the surface water, may perfectly well co-exist with a truly level course of each molecule. A billiard ball runs

along a level table by an impulse from the cue quite as naturally as if it rolled on an inclined plane by its weight. The notion of "a head of water," as a necessary condition, is a fundamental misconception in most of the received theories of oceanic currents, though such a head may be produced if a current be resisted or deflected.

(61.) The equatorial current of the Atlantic, as we have stated, bifurcates off Cape St. Roque, and a branch called the Brazil current runs southwards—inferior in volume to the Gulf Stream. The projection of the South American coast, and the absence of any deep hollow, like the Gulf of Mexico, affording no focus of concentration, a small portion only of it coasts along at about 300 or 350 miles from shore up to the extremity of the continent, while the main body performs in the South Atlantic much the same sort of evolution as the offset of the Gulf Stream in the north. The further progress of this stream is by no means well made out. It is no doubt swept round in an eddy in some respects analogous to that in the North Atlantic basin, so as to form what is called the "connecting current of the South Atlantic," which runs nearly due east about the 33d parallel of south latitude; but in what way it is returned into the equatorial circulation, or whether so at all, does not clearly appear. It has been considered as finding its way at the Cape into the Southern Ocean.

More probably a portion returns to the equator, and a portion escapes into the Southern Ocean, giving the Cape of Good Hope, however, a wide berth.

(62.) The equatorial current of the Pacific preserves a steady course, from its origin on the west coast of America across the whole Pacific basin, until it nears the Asiatic coast, where (as in the Atlantic) it bifurcates —the larger portion, however, being carried southwards through the broken channels between Borneo and New Guinea, to sweep the northern and western coasts of Australia, while the smaller branch, under the name of the Japan current, skirts the outside of the island barrier of the eastern Asiatic coast, imitating in the North Pacific, as nearly as the form of its basin and the narrowness of its opening into the Arctic Sea will permit, the course of the Gulf Stream in the North Atlantic. For it sends only a small shoot north-easterly up to the straits, while the main body, curving round, takes a great sweep along the Californian coast till nearly off the entrance of the Gulf of California, where it turns to the west, and regains the equatorial circulation. For nearly half the year (December-April) it is partially prolonged along the Mexican coast by the "Mexican coast current"—an alternating drift produced by monsoons setting along that coast.

(63.) In the North Pacific, in the latitude of Owyhee, and over an area of nearly 50° of longitude to the east-

ward of that island, that is to say, within the area encircled by the great eddying stream above traced, occurs a somewhat anomalous counter-current, or system of currents, running eastward, which in all probability result from peculiarities in the configuration of the bottom of the ocean—perhaps to shallows or to submarine coral elevations, which entangle and deflect a portion of the equatorial current. This and some other of the North Pacific currents are as yet far from well understood.

(64.) To understand the currents of the South Pacific, we must remember, that while the northern portion of the great equatorial drift (with exception of what can find a passage through Behring's Strait), merely eddies round the almost closed North Pacific basin, its southern waters find an escape, and enter the general circulation of the world through the Indian Seas. The Pacific, then, would be drained of its waters were it not replenished from the southern ocean, and we find accordingly that it is so. But this condition implies a northward direction given to the water drifted by the north-west Antitrades, which, combined with the movement to the south-east those winds alone would tend to impress, overcomes the southerly element of that motion, and leaves the east outstanding. Thus originate two leading currents known as the Antarctic drift current (of cold water bearing icebergs) and the South Pacific current, both setting into the concavity of the South

American west coast (the latter prolonged into what is known by the name of the Mentor drift current), together with a general drift of cold water to the southward of both these, which takes the form of a bifurcating current about 45° S. lat., nearly opposite the isle of Chiloe, and about 600 geographical miles from the coast. One portion proceeds to and rounds Cape Hoorn, as the "Cape Hoorn current;" the other skirts the whole western coast of South America, as the "Peruvian or Humboldt's current" (attention being first drawn to it by that celebrated traveller), interposing itself between the Mentor drift and the coast, till off Payta, in latitude about 4° S., it turns westward, and joins in the south equatorial circulation.

(65.) The currents of the Indian Ocean north of the equator are complicated by the monsoons, caused by the proximity of the Asiatic coast, and it is only over the region of the S.E. trades, and about the 20th parallel of south latitude, that a general and steady westward set of water takes place. This follows, *mutatis mutandis*, the same laws as in the Pacific, the ocean being open to the south. It bifurcates about the 75th degree of east longitude, one portion taking its course north of Madagascar, and then curving southward as the Mozambique current along the African east coast, the other, passing Madagascar on the east side, and pursuing a direct course towards the Cape of Good Hope, where the

two branches rejoin. A portion only of the stream so produced shoots southwards past the Cape as a warm current, but the greater part is suddenly deflected and driven back in an eddy or counter-current, running nearly eastward, by the cold water setting in from the south (bearing icebergs) to supply (just as in the case of the Pacific) the deficit of water, and carrying out precisely the same system of reaction as in that ocean. The drift produced by the prevalent north-west winds beyond the southern tropic, has the southerly portion of its momentum destroyed by the general equatorial indrift and overcome by this cause, the easterly subsisting, and the result is a north-easterly stream bifurcating off Cape Leewin about 105° E. long., and sweeping the western and southern coasts of Australia, the former portion (just as in the case of the corresponding portion of the Pacific supply current) reverting west, and joining in the equatorial circulation, the other going forwards in part supply of the Pacific deficit. We have been perhaps more diffuse on the subject of the oceanic currents than the nature of this essay may seem to justify; but some such detail seemed necessary to vindicate to the winds their supremacy in the production of currents, without calling in the feeble and ineffective aid of heated water, or the still more insignificant* influ-

* Insignificant for such a purpose, but not for some others, when its accumulated effect in long periods of time is regarded.

ence of insect secretion, which has been pressed into the service as a cause of buoyancy in the regions occupied by coral formations.

(66). *Tides and Waves.*—The tides are in the nature of forced oscillations (*i.e.*, such as are maintained against continued resistance and unconformable oscillatory tendencies in the system of waters subjected to them) maintained by the sun and moon, each of which produces and maintains such an oscillation, which, in virtue of the law of superposition of small motions, co-exists with the other, and either conspires with, or contradicts it, according to the phases in which they happen to be at a given time and place. The action of either luminary consists in a difference of attractive force exerted by it on the solid nucleus of the globe, and the covering ocean, whence arise disturbing forces analogous to those by which the motions of the moon are affected by the sun's attraction. If the disturbing luminary maintained a constant position with respect to the earth, the effect would be to produce a distortion of figure in the ocean surface, surrounding the whole globe (or which would so surround it, if entirely covered with water), having the form of a slightly elongated ellipsoid, the two vertices of which, were the waters instantly to assume a form of equilibrium under the acting forces, would be the one precisely under, the other precisely opposite to, the points at

which the luminary is vertical. This, however, is not the case, the forces shifting their point of action before the ellipsoid has time to form. Thus a wave is produced, which pursues the luminary round the globe.

(67.) The height of the wave thus produced by the moon is to that produced by the sun as 100 to 38. Their mean periods of revolution about the globe are also unequal, being respectively the lunar day of 24h. 54m., and the solar day of 24h. They conspire, and have a common vertex when the sun and moon are in conjunction or opposition (*i.e.*, at new and full moon); in which case the joint tide is the sum of the separate ones, and is called spring-tide. From these points the lunar lags behind the solar wave until the quadratures of the moon, when the high water of the moon coincides with the low water of the sun, and the joint tide is the difference of the separate ones, and is called neap-tide. And it is therefore by assiduous observations of the heights of the tide at the conjunctions and quadratures that, the sum and difference becoming known, the proportions of the two are ascertained (as above), the rise and fall of the spring and neap being as 138 to 62, or nearly as 7 to 3. The greatest tides occur when the luminaries are nearest, and pass most nearly vertically over the place of observation.

(68.) The depth of the sea varies so much, and the form of its basin, taken as a whole, is so interrupted by

the land, that it may be doubted whether, were the action of the luminaries at once suspended, their tide waves would perform even a single revolution with any sort of regularity, and in the course of two or three, would be so broken up and confused by reflexion to and fro, as to destroy all vestige of a tide. Hence it follows, that the tides for the time being may be considered as *almost* completely commanded by the then actual position and proximities of the luminaries, the free oscillations of the sea in its bed being quite subordinate to the forced wave generating them. In consequence (as is always the case in forced oscillations), every periodicity in the action of the forcing cause is propagated into the oscillations, and records itself in the recorded height of the tide on every point of every coast, but at each point, at a greater or less interval from the culmination of the luminary, according to its local position and the more or less circuitous course taken by the tide-wave to reach it, and which special observation can alone determine. This interval is called the *establishment* of the place.

(69.) The motion of the water in the tide-wave is totally unlike that in an ordinary surface-wave, such as the wind produces. When a narrow wave of this latter kind, or a succession of such waves of equal breadths and heights, is formed in deep water, a light floating body, as a cork, revolves either in a vertical

circle, or an ellipse not very different from one, having the longer axis vertical. But in the tide-wave the movement of each particle may be regarded as performed in an excessively elongated ellipse, the *shorter* axis of which is vertical. The breadth of the tide-wave from crest to crest, supposing all the earth covered, would be half the earth's circumference, or 12,500 miles, in comparison of which the depth of the sea is insignificant; and the slightest consideration suffices to show that as all the water which goes to form the elevated portion must be brought from that depressed, this can only take place by a lateral approach of the vertical sections of the sea when the water is rising, and their recess from each other when falling—*i.e.*, over a quadrant of the globe in either case, which is only another way of expressing an alternating forward and backward horizontal current at any given place—with this especial peculiarity, viz., that these currents (the flow and ebb current) run *most rapidly* at the moments of high and low water; the instants of *most rapid rise and fall* being those of "slack water," or no current one way or other. In fact, it is obvious that the surface must be rising most rapidly when water is *setting in equally both ways to*, and sinking most rapidly when setting *out equally both ways from* the place; in neither of which cases can there be any current *at* the place.

(70.) The tide-wave differs also from a wind-wave in

another very remarkable point. It affects the whole depth of the ocean equally, from the bottom to the surface, while the wind-waves, even in the most violent storms, agitate it to a very trifling depth. For the force which acts to produce the former, which is what in the lunar theory is termed the *tangential* element of the disturbing force,* is exerted equally in every portion of the vertical extent of the water, while those producing the latter are strictly confined to the surface. Hence it would at first sight seem that the tidal action must be very violent at the bottom of the sea; and in shallow seas it is so, but not in deep water. A tide-wave of four feet in total height (between high and low water), which is that of the tide at the Atolls of the Indian Ocean, advancing over a sea 30,000 feet deep, implies in each particle an alternate advance and recess of 2800 feet in its total extent; but this movement, being spread over 6 hours either way, is nowhere very rapid.

(71.) In shallow seas, however, the actual movement to and fro is more rapid in the inverse ratio of the depth of water, and this is seen in many remarkable instances, as, for example in the Race of Alderney, and the seas in the island channels of the Orkneys, and the celebrated Maelstrom off the Norwegian coast, as well as in the rapid streams which flow all round our own coasts, and are familiar to every seaman. It is this

* Airy. On Tides and Waves (Encyc. Metropol.), arts 28, 279

which gives the tides their drifting and abrading power on the materials of the coast.

(72.) Both the sun and moon, on a general average, are vertical over the equator, where, therefore, if the sea covered the globe, would be the region of highest tides, and round which zone they would circulate uniformly; but the equatorial sea being broken up into three great basins, and open water existing only to the southward of the three great continental masses, the phenomena of the tides are complicated in a very singular way. In each of these basins the equatorial tide has to take a fresh start from the eastern side, with every fresh upper and lower transit of the producing luminary, and is destroyed or confused by reflection on the western coast before the creation of a new wave, while in the open part of the Southern Ocean the tide-wave circulates unimpeded, and spreads in to the three oceans, up which it runs *as a free wave* from south-east to north-west, overtaking in its progress, and amalgamating with, the partial equatorial tides or forced waves proper to either ocean, and their reflected portions. In spite of all the complications so induced, however, and of those additional ones which arise from the shoaling of seas and the narrowing of channels, as a general fact two high and two low waters occur everywhere in the course of a lunar day of 24 h. 54 m., the solar and lunar tides never contradicting each other

combine as to produce a double maximum in their combined wave. The day and hour of occurrence of the highest spring-tide next following the conjunction of luminaries being observed, informs us not only of the "establishment" of the place, but also of the *age* of the tide, or that particular original tide-wave, of which any one circuitously arriving at a place, may be a branch. Thus the age of the tide in the port of London is two

on the coast of Spain, thirty-six hours. By *determining these particulars at a series of points along* all the coast lines, it becomes possible to construct a chart of *cotidal* lines, or those of contemporaneous arrival of the same tide, however subdivided, as has been done with extraordinary perseverance and success by Dr. Whewell. From his researches we learn,

(73.) 1*st*. That whereas the forced equatorial tide in a continuous sea would run round the globe in 24 h., and therefore with a mean velocity of 900 geographical miles = 1050 statute miles per hour, it requires 12 h. to run up the Atlantic from 50° S. to 50° N. lat., giving an average rate of about 500 geographical miles per hour. In the Atlantic, then, it is more in the nature of a free than of a forced wave.

(74.) 2*dly*. That its rate of advance is mainly determined by the depth of water. When it enters the Atlantic its front runs nearly from N.E. to S.W. but in its progress it becomes curved and convex northwards,

till it approaches the southern tropic, where its progress is retarded again in the interval from thence to the equator, just where the appearance of islands (St. Helena and Ascension) afford an indication of less depth. From the equator northwards, its progress again becomes rapid, and the increasing convexity of the lines of successive hours marks as clearly as soundings (since obtained) would do, the deepest channel. Thus the cotidal line corresponding to the eleventh hour of its progress, which at its eastern extremity rests on Cape Blanco (lat. 21° N.) and at its western on Porto Rico (19° N.) has its front advanced to the north nearly to the bank of Newfoundland (46° N.), and the point of its farthest advance precisely on that part of the sea where (as we have seen in art. 37) the great submarine cross valley of the North Atlantic is situate. Advancing further north, the cotidal lines of the successive hours close up, in correspondence with the diminishing depth of the North Sea, and round the Irish coast, indicate a velocity not exceeding 150 miles per hour, while in the channels the wave advances still slower, and they are crowded still closer.

(75.) Further and very remarkable corroborations of the same theoretically demonstrable law appear wherever the advancing front of the tide-waves stretches across the opening of any great bay or recess of the coast line. Such is the case in the hollow of the South American coast off Patagonia, between the river La Plata

and Cape Hoorn; and again in the Indian Ocean, in the Arabian Gulf, and the Bay of Bengal, in which last, as the rate of advance of the wave diminishes, the extent and force (as a necessary consequence) of the aquatic movement increases, both the height and the ebb and flow current are exaggerated, and result in the phenomenon of a *Bore*, or sudden and violent wave rushing up the Hooghly River with such impetuosity as to sweep everything before it. The same thing takes place in many other estuaries, or gradually expanding mouths of rivers, which receive and concentrate the tide; as, for instance, in the Garonne, and in our own Severn, where the spring-tides at Chepstow (which in mid-ocean, as at St. Helena and Ascension, do not exceed three feet) rise to forty, and where at such times a bore nine feet in height runs up stream. The bore of the Chinese river Tsientang advances up that river at Hangchau like a wall of water, extended across the river, thirty feet in height, and advancing at the rate of twenty-five miles per hour, sweeping all before it. In the Amazon River, at the equinoxes (when the equatorial tide is at its maximum), during three consecutive days, bores of twelve or fifteen feet high rush up the river with each high water; so that, along the course of the stream, up which for 200 miles from its mouth no less than eight tide waves are simultaneously advancing, as many as five bores are sometimes at once in progress.

(76.) The effect of concentration, by the gradual approach of the shores, and the shoaling of the bottom, is nowhere so strongly exemplified as in the Bay of Fundy, where the tide not uncommonly rises fifty feet, and, as is said, on some occasions to more than double this height. The whole of the tide-wave between Halifax and Charleston is made to converge by the shores of Nova Scotia on one side, and the United States on the other, to the entrance of this bay. A ship known to strike and remain fixed on a sunken rock at high water there during the night, and at daybreak the crew have been astonished to find themselves looking down a precipice into water far below.

(77.) The tide which flows round the British Islands, on the west side, bends round the north of Scotland, and enters the German Ocean from the north, after traversing which, it meets the tide of twelve hours' earlier origin which has entered by St. George's Channel. Hence arises a singular complication; the former tide mainly clinging to the British, and the latter to the continental coast, and producing a revolving wave and nodes of undulation; and, in consequence, there is a point in the North Sea whose existence was pointed out *a priori* by Dr. Whewell, and verified by observation, where the rise and fall of the tide is *nil.*

(78.) The tides of the Pacific are but ill understood. In some parts of it (as in the Atlantic) they are of very

small magnitude, as far as rise and fall is concerned, so that at some points, as at the Sandwich Islands, they may be said to be entirely masked by the effect of the land and sea breezes, and the diurnal variation of the pressure of the air: and a single feeble tide, at fixed hours in the day and night, occurs in place of the usual double rise and fall at hours continually varying. At Singapore, also at the Keeling Islands, and at Petro-[redacted] similar phenomena occur; due to local peculiarities. At Tonquin also (at Batschan) there is only a single tide; but this is explained by the interference of tides which reach it at the same time in different phases, and by different channels, combined with the "diurnal inequality" of the two high waters (a very generally observed phenomenon), which annihilates one of them, but leaves a portion of the other outstanding.

(79.) *Wind-waves* are small at their first origin, commencing with a mere ripple, or, as the sailors term it, "a cat's paw," on the water—"darkening like water in the breeze." But each wavelet, as it advances, acquires increased height by the continual pressure of the wind, according to a law which has been clearly deduced from strict dynamical principles by Mr. Airy in a very remarkable paper on Tides and Waves, forming part of the *Encyclop. Metropol.* Hence it is that the larger waves are not developed in narrow seas, or when the wind blows off the land; they require breadth of

water and continued pressure *a tergo*, for their formation. The greatest waves known are those off the Cape of Good Hope, under the influence of a north-west gale (the storm-wind of that region), which drifts the swell round the Cape, after traversing obliquely the vast area of the South Atlantic. In such gales, waves are there met with of forty feet in height, so that two ships in the trough of the sea, with such a wave between them, lose sight of one another from their decks. Off Cape Hoorn, also, waves of thirty-two feet from crest to trough have been observed. In our own seas the waves rarely exceed eight or nine feet in height.

(80.) There exists a relation between the breadth of a wave, its velocity of progress, and the depth of the water on which it travels, which has been embodied by Mr. Airy in the following table:—

Depth of the Water in Feet.	Breadth of the Wave in Feet. 1	10.	100.	1000.	10,000.	100,000.	1,000,000.	10,000,000.
	Corresponding Velocity of Wave per Second in Feet.							
	2·262	5·320	5·667	5·671	5·671	5·671	5·671	5·671
	2·262	7·154	16·888	17·921	17·933	17·933	17·933	17·933
10	2·262	7·154	22·264	53·390	56·672	56·710	56·710	56·710
1,000	2·262	Do.	22·264	71·543	168·83	179·21	179·33	179·63
10,000	2·262	Do.	Do.	71·543	220·24	533·99	566·72	567·10
100,000	2·262	Do.	Do.	Do.	226·24	715·43	1688·3	1793·3

The conclusion of Professor Bache respecting the depth of the Pacific, noticed in art. 40, is founded on this Table. And by a similar principle of calculation, grounded on

the progress of the tide-wave (regarded as a free-wave) running up the Atlantic (art. 73), viz., that a wave 6000 geographical miles in breadth from crest to crest travels its own breadth in twelve hours, we find for the *mean* depth of the whole Atlantic from 50° south lat. to 50° N. 22,157 feet, a result perfectly in accordance with what we know from numerous soundings of its northern basin, and what may reasonably be concluded from the comparatively few obtained in its southern.

(81.) As the wind supposed to blow off shore, continues to act on a wave, it increases both in length and breadth, and the water deepening, its velocity of progress increases rapidly. The depth of water to which the agitation of a wave extends perceptibly, never bears a very large proportion to the dimensions of the wave, either in breadth or height, the motion diminishing in geometrical progression, as the depth below the surface increases in arithmetical; so that at a depth equal to the breadth of the wave, the motion is diminished to one 534th part of that at the surface. In the case of a wave, then, a quarter of a mile in breadth, and forty feet in height, the displacement of the water at a depth of 1320 feet, in its passage over it, would be less than an inch, and would be incapable of disturbing the smallest grain of sand.

(82.) When waves cross each other, they are simply superposed, and in place of dividing the water into

parallel ridges, they break it into lozenges. In this case, the motion of each particle of the surface water, besides that of rising and falling, is one of circulation in a horizontal plane, and a small portion of the surface changes its inclination to the horizon in what is called a vorticose manner, a perpendicular to the surface (as the mast of a ship floating on it) revolving conically, by a combination of pitching and rolling distressing to the passengers, and trying to the vessel. This crossing of waves, especially when more than two series cross one another, forms what is called a "chopping sea." Such seas occur, 1*st*, when a series of waves, rolling into an extensive bay, meet at oblique angles the waves reflected from its shores, as is very frequently the case in the Bay of Biscay. 2*dly*, When the wind, after blowing long and fiercely in one direction, veers suddenly to another; which happens especially in those hurricanes called cyclones, or revolving gales, which produce waves travelling at once towards all points of the compass, the combination of which, near the centre of the whirlwind, produces a sea of the most fearful description. 3*dly*, When a storm in one direction acts on a sea in which there exists already a long rolling swell setting in from a great distance in another, called a "ground-swell," the consequence of a far remote storm which has never made itself sensible in any other way at the place of the ship.

(83.) By far the largest waves, however, are those

which owe their origin to earthquakes. On such occasions great tracts of the ocean-bed are often suddenly uplifted or depressed, and the result is necessarily a vast wave running out from the spot in all directions. One such wave has already been mentioned. In the earthquake which destroyed Lisbon in 1755, a portion of the coast-line suddenly sank to a depth of 600 feet, and the result was a wave of 60 feet in height, which swept over the land, ravaged the whole coast of Portugal, and was propagated seaward quite across the Atlantic to the West Indies. At Madeira it rose and fell 12 feet.

(84.) When a wave runs forward into shoal water, the friction retards the movement of the lower particles, those of the upper continuing. The circle described by the water molecules gradually passes into a more and more flattened ellipse (WEBER *Wellenlehre*), and at length the wave *breaks:* its crest curls over, and precipitates itself forward on the shore, up which it rushes, the under-water at the same time racing back, and tearing up the beach in its backward course. Hence the abrading and destructive action of the surf on a sea-beach. Certain coasts are particularly infested with a heavy surf, such as that off Madras, where the surf habitually breaks at such a distance from the beach as to render landing always difficult and dangerous, and sometimes impossible. The great waves which roll in from the Indian Ocean sometimes break there in nine

fathoms water, and at a distance of four miles from land.

(85.) The force of waves, when breaking against an obstacle, is enormous. Their effective pressure during violent storms has been estimated as high as 6000 lbs. per square foot. The waves breaking against the base of the Eddystone lighthouse, have been known to dash, up above its top to 150 feet above the sea level, and descend like a cataract on its summit. In the great Barbadoes hurricane of 1780, cannon, which had been long lying sunk, were washed far up on shore, and found high and dry on the subsidence of the storm.

(86.) *Coral Formations, Atolls, Reefs, Lagunes.*—A very large area of the tropical seas, both in the Indian and Pacific Oceans, is dotted over with islands, the upper portions at least of which are the work of those singular organisms of the genera astræa, meandrina, and caryophyllia, which secrete from the sea water the *nidus* which they inhabit in the form of continuous rocky masses, perforated according to regular patterns, and known by the name of coral. The animals themselves live and work only within certain very moderate limits of depth, not exceeding ninety fathoms; and whether those now living are to be considered as successors or prolongations (by a process of gemmation) of those which have perished *in situ*, does not seem well made out.

(87.) The coral formations are chiefly confined to the Indian and Pacific Oceans, between the parallels of 30° north and south. The Arabian and Persian Gulfs, and the Red Sea, are full of them, and between the coasts of Madagascar and Malabar, the whole ocean may be considered as a great coral sea. Along the east coast of Australia, and stretching thence to New Guinea, they form barrier reefs of the most dangerous character, which prevent all access to the coast, except through narrow channels occurring only at rare intervals. The "Great Barrier Reef" extends from Breaksea Spit, in lat. 24° 36′ S., to Bristow Island, 9° 15′ S., with a mean breadth of 30 miles, a length of 1100, and an area of 33,000 square miles. But the most curious and striking peculiarity of the coral formations is their tendency to crown every summit rising up from deep water, and to form, upon sunken rocks, circular basins or lagunes, a *fleu de l'eau,* called Atolls, surrounded on every side with water of unfathomed depth, and shelving off in the most precipitous manner. Of these, the most remarkable instances in the Indian Ocean, is the chain of islands, or rather groups of islands, running directly south across the equator from the western extremity of the peninsula of India, the Laccadive, Maldive,* and Chagos Isles. These consist of "a series of circular assemblages of islands, the larger groups being 40 or 50 miles in

* See Moresby and Powell's beautiful charts of the Maldive Atolls.

their longest diameter. On the outside of each circle or *atoll*, are coral reefs extending to a distance of two or three miles, beyond which are no soundings at immense depths. But in the centre of each is a lagune from 15 to 20 fathoms deep." It has been considered, with great probability, that these atolls crown the craters of extinct and submerged volcanoes; and from the excessively sudden and precipitous manner in which many of them in the Pacific spring up from deep water, the lower portions being formed of *dead* coral (for the animal lives and works only at or near the surface), an argument almost irresistible has been drawn by Mr. Darwin in favour of a slow but continual subsidence of the bottom of the ocean in which they occur, the animals constantly raising the summit to the surface as the base subsides. The upper portion of their work is battered by the sea, which heaps up the broken fragments on the windward side, leaving generally an opening into the lagune to leeward, and thus forming, as it were, harbours of refuge of great security, with free access at all times. This peculiarity has been insisted on by Sir C. Lyell as an additional and very cogent argument for their gradual subsidence, as it is difficult to imagine any other cause by which the leeward opening could constantly be kept unobstructed.

(88.) In the Pacific, the most remarkable coral formations are those of the Caroline Islands, a vast assem-

blage of coral groups, extending over more than 20° in longitude, and 5° in latitude, the Society Isles and the so-called Dangerous Archipelago. Indeed, every island yet examined in the wide district termed Eastern Oceania, consists either of volcanic rocks, or coral limestones.

(89.) It is one of the peculiarities of these Zoophytes, that they always build perpendicularly upwards. This, while it serves to explain the precipitous character of the external wall of their lagunes, may serve in conjunction with the great depth from which they rise, to give some idea of the duration of the period in which the subsidence of their foundation has been in progress —such steepness being of extreme rarity on coasts where no coral exists, and where the usual action of the sea, except on the hardest granite, invariably shoals the water into a more or less gradual declivity.

(90.) *Phenomena of the Polar seas.—Floating Ice—Icebergs.*—Beyond the 56th parallels of latitude, as we have seen, the temperature of the water is lower at the surface and rises as the thermometer descends, till the level of 39° is reached. The sea then, even in deep water, becomes frozen at the surface in the winter months, or rather through all that portion of the year which intervenes between the beginning of September and the latter end of June—July and August being, in high latitudes, the only open months. Sea-water freezes at a lower temperature than fresh (28½° Fahr.),

but its ice, like that of fresh-water, floats, and nearly with the same buoyancy. It may, indeed, be doubted whether salt-water ice be really anything else than fresh with a portion of concentrated brine entangled in its pores. Snow falling and floating on water of 28°, does not of course melt, so that the Polar Seas become coated with a stratum of perfectly fresh ice over very extensive tracts. The broken masses detached from the coasts also, around which the ice accumulates in the long winters into cliffs and glaciers of vast height, and hundreds of miles in extent, and which, when set afloat, drift along as icebergs, by the effect of currents, are necessarily fresh. In estimating the magnitude of these masses, it must always be borne in mind that the specific gravity of ice being only 0·9, only about one-tenth of its bulk projects above the surface.

(91.) There can be very little doubt that, in the winter time, the surface of the ocean at both poles is entirely frozen; but at the North Pole, it is probable from many indications, that open water exists over a very large area of the central polar basin, during a considerable portion of the warmer months. Although the northern coasts of Europe and Asia, from Nova Zembla to the extremity of Siberia, are always lined with ice, yet, in advancing out to sea-ward in sledges, from Kotelnoi Island and the mouth of the Kolyma River, in lat. N. 76° and 72°. Lieut. Anjou and Baron

Wrangel found open ocean as far as the eye could reach; and the same has been observed by Inglefield and Kane (the latter viewing it from "Cape Constitution," 540 ft. in altitude), in lat. 81° 22′ N., in Kennedy Channel, at the north end of Smith's Sound. In the land-locked and intricate channels between Greenland and the north coast of America, the obstruction very frequently continues, however, during the whole summer, and *even several successive ones*, as the annals of Arctic exploration only too emphatically witness.

(92.) When, under the influence of the advancing season, the "field-ice" of the general surface breaks, it becomes heaped together in sheets piled on each other into what is called an "ice pack," shewing in lines the thickness of the sheets, which often extends to 30 or 40 feet. The wild confusion which a storm creates in such a "pack," is more easily imagined than described. When extensive ice-fields meet, which they often do, under the influence of opposing winds and currents, their enormous momentum crushes together the edges in contact, breaks them up, and drives them one over the other into ridges. Occasionally these floating fields come into collision with icebergs, which are making their way under the influence of the current, by which (on account of the great depth and volume of the submerged portion) they are entirely commanded, while the "floes" drift at the mercy of the winds, when an awful

scene of destruction takes place, the floes, of course, giving way, tearing up, and flying to pieces in all directions.

(93.) To give an idea of the quantity of ice which is carried out of the polar regions, independent of the icebergs, and drifted into warmer temperatures, we need only instance the case of the Resolute, exploring-ship, which, having been abandoned by reason of its getting inextricably engaged in a vast field of ice in Melville's Straits, was found afterwards in Baffin's Bay, having been carried 1000 miles from its former position by the drift of an ice-field 300,000 square miles in extent, and 7 feet thick. A similar occurrence carried Captain De Haven, of the U. S. Navy, in a mass of frozen sea water an equal distance south of his position in the mid-channel of Wellington Straits.

(94.) Little of the *floe*, or surface ice, however, escapes unmelted from Baffin's Bay: it is speedily broken up and destroyed by the waves in open water, and it is only the great detached masses which float to any considerable distance from either polar circle into the temperate zones. In the Atlantic they are seldom met with below 40° N. lat., being destroyed by encountering the Gulf Stream. In the North Pacific, their access from the Polar Basin being barred, they do not occur. In the Southern Ocean they attain as far as 40° S., and are very often met with in rounding the Cape of Good Hope, at some distance from land.

(95.) These bergs, from the mode of their formation, being detached by fracture from glaciers projecting into the sea, and from barrier lines of ice cliff, and being afterwards subjected to the melting influence of the air, assume the most uncouth and extraordinary forms, sometimes picturesque with towering pinnacles and overhanging cliffs, and always grand and awful. They have been seen as much as 600 feet in height, but when met with at sea are seldom more than 200 or 300. They spread a sensible degree of cold in the air, accompanied with fog, for great distances round them, and form one of the chief dangers in navigating the North Atlantic.

(96.) Many of the bergs which drift out to sea, having been the extremities of glaciers while in attachment to the coast, are loaded with broken fragments of rock and other materials, which have been heaped on them by casualties of weather, and the fall of rocks during their gradual descent to the sea level. These they carry with them wherever they may drift, and ultimately deposit at the botom of the sea on melting. Icebergs have been encountered in the North Sea covered or interstratified with ancient soil, among which were the bones of mammoths and other extinct animals.

(97.) From the south pole, a sea, open (at least so far as land is concerned) or nearly open, extends, surround-

ing it except between the meridians of 160° and 170° E. longitude and the parallels of 70° and 80° S. latitude, which is occupied by the coast of Victoria Land, discovered in 1841 by Sir J. C. Ross. From the southernmost accessible point of this coast, in lat. 78° 15′, extends for 450 miles to the eastward an unbroken vertical cliff of ice, being 180 feet above the water, and therefore about 1000 feet in thickness—floating in water 280 fathoms in depth (1680 feet), though probably connected to the south with an extension of Victoria Land. With exception of this, and some similar masses also connected with land, the Antarctic Sea is less unbrokenly coated with field ice than might be expected, the swell from the great oceans with which it is connected breaking the fields up into floes of no great magnitude. But, on the other hand, the "packed ice," which results from the fracture and piling up of the field ice, accumulates in immense quantities. Sir J. C. Ross, in the daring voyage of the Erebus and Terror, had to force his way through 1000 miles of such obstructions.

(98.) In consequence of the intense cold of the icy surface, contrasted, as it sometimes is in summer, with the warmth of the air, the phenomena of atmospheric refraction are exaggerated in these regions in a most extraordinary manner—the forms of icebergs, rocks, etc., are seen drawn up in vertical altitude, and spread out

at their apparent summits laterally, so as to present no resemblance to their real form. One of the beneficial consequences of the great amount of refraction is the earlier appearance of the sun above the horizon, and its later disappearance, by which the dreary polar winters are shortened by several days.

(99.) Another phenomenon, which is witnessed in its highest perfection in the polar seas, and, in general, in high north and south latitudes, is the Aurora. The magnificence of its displays, as recorded by those who have witnessed them in the arctic regions, is such as those who have seen it only in our latitudes can hardly conceive. It is described as an immense curtain, waving its folds like the canopy of an ample tent agitated by the wind, and fringed with a border of light of the richest colours and vivid brilliancy. The impossibility of wintering in very high southern latitudes cuts off the most advantageous opportunities of observing auroral exhibitions in the antarctic regions.

(100, *a.*) Professor Loomis in a memoir recently published (American Journal of Science and Art, vol. xxx.), has traced with much care and research the district over which this phenomenon exhibits its maximum development in the Arctic regions. Eighty auroras annually are seen on an average in every part of a zone surrounding the north pole, like a belt of an oval or Lemnisco-elliptic form, varying in breadth from 9°

to 12°, and having its longer axis situated on the meridians of 60° W. and 120° E. longitude from Greenwich, on the former of which its northern limit occurs at 62°, and in the latter at 75° of N. latitude, so that its interior occupies in its longer direction 43° of latitude, through the pole: in its shorter only 31°. The medial line of this belt passes across Iceland, the North Cape, the Gulf of Obi, the whole of Northern Siberia, the mouth of the Mackenzie River, the centre of Hudson's Bay (where the greatest breadth of the belt occurs), and Nain, on the coast of Labrador. This band of greatest development is bordered, both internally and externally, by one of less average frequency (forty displays per annum), of about 5° in breadth each.

(100.) THE LAND.—*Its Coast-lines, Harbours, Sea-cliffs, Beaches, Shingle-drifts, Tidal abrasion, Estuaries, Deltas.*—We have mentioned in arts. 12, 15, the more general features of the coast lines of the great masses of land. These, as well as the general forms of all the continents, will be best seen and understood from the projection of ninety-seven hundredths of the whole surface of the earth, presented at one view in Plate A, or rather in the sector, comprised within the medial 120° of the semicircle in that plate; each degree of that sector comprising three degrees of longitude; and one quarter of the surface being repeated on either side, so as to afford a complete general view

of the Pacific Ocean without turning to another map.* But it is their minor local irregularities of outline which, in the magnitude and convenience of harbours, estuaries, and river mouths, accessible at all seasons, and the protection and facility of communication with the interior these afford, constitute a feature of the last importance to the well-being and commercial intercourse of the countries they border. In this respect there is a marked and vast difference between the several regions of the land, which has exercised, and must ever continue to exercise, a most powerful influence in determining the relative degree of civilization of nations, and, what is of greater importance, the more or less cosmopolitan character of that civilization. In this respect Europe, and the eastern coasts of North America, stand pre-eminent. It is true that the great Archipelago of the east affords innumerable and excellent positions of this nature; but their very multitude and disconnection fit them rather for nests of piracy, or for dependent emporia of commerce *in transitu*, than for the seats of great, compact, and united communities.

(101.) The capacity of any region of the globe for external communication may, to a certain degree, be very fairly estimated by a comparison of the extent of

* The principles of this projection are explained in a paper communicated by the author to the Royal Geographical Society, and will appear in the forthcoming volume of the transactions of that body.

its coast-line with its superficial area. Europe, for instance, with an area of 3,400,000 square statute miles, has 20,000 statute miles of coast-line, being at the average rate of a mile of coast for every 170 square miles of surface, and of which only about 3000 miles is of difficult access. Asia, with 17,600,000 square miles of surface, has 33,000 miles of coast (or one to 533), nearly a fourth part of which is arctic, and all but inaccessible. Africa, with 11,300,000 miles of surface, has a coast of 16,500 (1 to 420), singularly destitute, in every part of its outline, of good harbourage, and with some of its great rivers barred, and others pestiferous. On the other hand, the area of North America being 7,200,000 miles, has a coast-line (1 to 260), of 28,000, of which, however, nearly a third being arctic, is useless as a sea-bord. South America, with an area of 6,800,000 miles, and a coast line of 16,500 (1 to 420), presents a remarkable contrast between its eastern and western coasts, not so much in respect of indentation by good harbours, of which it has little to boast, as on account of the vast rivers which flow into the Atlantic, and afford a power of penetrating into the interior, *ab extra*, unexampled except in North America and China. Our own islands, Ireland in particular, are more richly supplied in this respect than any other territory of equal extent, with exception of Norway, the whole coast of which is one continuous chain of deep indentations, or fiords, but

whose rugged and precipitous character, and difficulty of accessibility on the land-side, owing to the rude and mountainous *nature of the* country, go far to neutralize this great natural advantage. The least favoured region in this respect is Australia—a mass of 3,500,000 square miles in area, but lying compactly within a very rounded general outline, having a coast but little indented, and nearly, in a very large portion of its eastern sea-bord, rendered unapproachable, except through particular channels, by the great barrier coral reef noticed in art. 87. Nevertheless, it possesses in Sydney perhaps the most perfect and magnificent harbour in the world, and one in which all its united navies might float in security.

(102.) One of the greatest advantages a harbour can possess is that of having, at some little distance off its opening, and in the direction from which tempestuous weather chiefly comes, an island to act as a natural breakwater, according to Virgil's description:—

> "Insula portum
> Efficit objectu laterum, quibus omnis ab alto
> Frangitur, inque sinus scindit sese unda reductos."

Such is the security and ready lateral accessibility on either side afforded to Portsmouth by the Isle of Wight, and to New York by Long Island. Table Bay owes what little security it may be considered to possess, in like manner, to the proximity of Robben Island. Where

such natural breakwaters are wanting, or insufficient artificial ones have often to be constructed, at vast expense, as at Plymouth and Cherbourg.

(103.) A sea-beach is a more or less gently sloping area, on which the breakers do their work of grinding to powder, and carrying out to sea, the fallen fragments of cliffs undermined by their action during high tides and storms, or precipitated by landslips. Such a slope, rising at a small angle (smaller in proportion to the fineness of the detritus of which it consists), surmounted usually by a somewhat steeper bank of shingle (loose stone not yet battered to powder), and backed to landward by a vertical or very precipitous escarpment, marking the limit so far attained by the encroaching ocean, and hollowed into caverns by its waves, is the almost invariable character of a coast line, except when (as in Norway, and on the west coast of Scotland) its material consists of the harder crystalline rocks, in which case there is often deep water close to the cliff, or rugged rocks in every stage of progressive destruction, forming a *talus* rising above the waves. It is therefore perfectly easy to recognise by these marks, when we find them in the interior of a country beyond the present reach of the waves, the existence of what was once a sea-beach, and thence to conclude the action, since that epoch, of elevating forces. Innumerable instances are met with in every part of the world of

such ancient sea-beaches elevated at various heights above the actual sea-level—for example, at Plymouth, at New Quay, near Falmouth, in many parts of Wales and Scotland (as in the celebrated parallel roads of Glenroy, clearly shewn by Captain Hall to be ancient sea-beaches); from Alten Bay to Hammerfest in Finmark (Bravais), in the Val di Noto in Sicily (Lyell), in the Morea, as described by Boblaye, and still more remarkably in South America, in the valley of Lima, near Baños del Puyo (Cruickshank), 700 feet above the present sea, and at Coquimbo (Hall). Lately a succession of raised beaches, like a vast flight of forty-one terraced steps, 480 feet in total height, has been described by Dr. Kane as occurring along the coast of Kennedy Channel, separating Greenland from the land to westward, commencing at 76° N. lat., and continued to "the Great Glacier," and the north of Grinnell Land, or North Victoria. This, then, is one of many cases in which the study of what is actually going on educates the eye and the intellect to discern what has passed; and it is thus that we recognise, in the escarpment of our chalk formations, the cliffs bounding that sea which has denuded of its chalky covering the whole of our Wealden country; and conclude the continued levelling action of the ocean wherever we find a hilly country cut down by such escarpments abutting on an extent of comparatively level ground.

(104.) The material so pulverized and washed down into deep water is transported by the tide-current to great distances. In the peculiar nature of the tidal undulation described in arts. 69, 70, we perceive the great transporting and distributing agency by which new strata are formed from the destruction of old ones. But the full effect of this power is only to be appretiated when we contemplate the rounded forms of hills, and the branching and sinuous valleys of a very large portion of the surface of the land where the action of the existing rivers, or of any conceivable amount of atmospheric precipitation, is quite inadequate to have performed the work of excavation, and where there is no evidence of sudden and violent convulsion. Witness our own chalk downs, much of our Wealden swells and slopes, and the gentle undulations which everywhere cover the surface of the lower lands in all countries—

> "Qua se subducere colles
> Incipiunt, mollique jugum demittere clive;"

and which can be referable to no other agency than tide-washing during a period of prolonged submersion in shallow seas. A large portion of the surface of France is one continued exemplification of this agency.

(105.) Loaded with the material so abraded, the tide-currents sweep along the coast a vast quantity of matter which they deposit in eddies, and thus alter the outlines of the coasts, silt up harbours, form sand-banks,

shingle-drifts, land-spits, and other appendages to coast lines (of which we have examples in the great shingle-drift of Dungeness Point and the Chesil Bank), and are active in producing one of the greatest impediments to navigation in the form of bars at the mouths of rivers, of which notable instances occur in the Rangoon River, the Meinam, the Senegal River, the Quilimane or Zambesi, and the Canton River, where there are two bars, Port Natal, and most of the harbours on the South African coast. Such bars are chiefly formed where the opening of the river to the sea is narrow, and not spread out into an estuary, which the tide tends rather to scour than to silt up.

(106.) Besides the material worn off from the coast by the action of the sea, a vast quantity is brought down by rivers, which accumulates at their mouths, forming deltas, the forms of which are greatly modified by tides and currents. The Ganges has been computed to deliver, on an average, into the sea annually 534,600,000 tons of solid matter; the Mississippi 292,700,000; and the Irawadi 102,500,000. No wonder, then, that in the course of ages deltas should accumulate. That of the Ganges extends across a space of 160 miles, and it has nearly the form of an equilateral triangle, considered as filling the area included by the Hooghly branch, and the innumerable smaller streams which cross like a network over its surface. The delta of the Nile, like that

of the Ganges, is formed in a fork of the river, about 90 geographical miles from the sea (though doubtless the sea, at some former period, occupied the whole space between the branches), and forms on the sea-bord a segment of a circle, having a chord of about 170 geographical miles, the outline being rounded off by the action of the currents sweeping the drift to the eastward, and bordered with a chain of salt or brackish lakes, separated from the sea by narrow sand lines. That of the Rhine, or rather the united delta of the Rhine, Meuse, and Moselle, constitutes the whole of Holland, and offers, in its northern part, the same phenomenon of a rounded outline and chain of low drift banks (Texel, Vlieland, Schelling, and Ameland), enclosing a shallow expanse of water (the Zuyder Sea), the rivers entering the sea by innumerable outlets to the south. On the other hand, the deltas of the Mississippi and the Lena carry out the rivers to great distances, and form very projecting points; that of the Mississippi, in particular, which is singularly ramified, and in which the main channel prolongs itself on land of its own formation, like the claw of some web-footed bird, far into the Gulf of Mexico, being increased by immense quantities of drifted trees, which meet together, and form a vast floating mass—the "Raft of Atchefalaya," which, in 1816, contained upwards of 250,000,000 cubic feet of timber, accumulated, in conse-

quence of some local obstruction, in only 38 years, and has been increasing ever since.

(107.) THE LAND, *continued.—Law of Distribution of its Materials—Geological Relations.*—One of the first things which travel teaches us is, that the materials of which the earth consists are not scattered chaotically, and at random, over its surface. Particular sorts of earth and rock occur largely and almost exclusively over some districts, and are wanting in others, and it is the business of geological science to furnish a clue to the intricacies of their distribution, and to point out the relations which subsist between adjacent districts in respect of material composition, and the conditions which have determined the form and extent of each.

(108.) A very superficial observation of the escarpments of cliffs, and other features of a country which lay bare some considerable depth of the ground, suffices to shew that a very large portion of the earth's surface consists of successive layers or beds of different material, or of the same with marking lines of separation, or thin layers of others interposed, while other portions exhibit no such character. Hence a division into *stratified* and *unstratified*. If these layers were strictly horizontal, and of equal thickness, the slopes of every hill, and the face of every cliff would exhibit a series of horizontal belts, running level lines around their contour, and defining the extent over which each would form the

surface soil; their superficial breadth being determined simply by the more or less gradual slope of the ground, and the thicknesses of the strata so intersected or "out-cropping." But this is found to be rarely the case; the strata are inclined to the horizon, and some more, some less so; and being intersected by or "out-cropping" at the surface, and that surface being an uneven one, the belts which they form on it neither follow level lines, nor are bounded by parallel outlines. It is therefore to the thickness, inclination, and *order*, if any, *of superposition of the strata*, that we have to look for a key to the extent, configuration, and order of arrangement, side by side, of mineralogical and agricultural districts.

(109.) So long as mineralogical characters only were referred to as distinctive of a "formation," it could never be positively asserted that any definite order of succession existed. The same kind of rock, a limestone for instance, might be found bordering in area, or overlying in level, many different kinds of rock. But when the attention of geologists came to be directed to the fossil remains of animals and vegetables imbedded in them, it was found possible to assign to each formation characters so definite, drawn from these its fossil contents, as to admit of an unbroken order of succession being recognised, not in one county or district, but over the whole surface of the globe. It is this grand general-

ization which, worked out to its full extent by modern geologists (the hint being furnished by a countryman of our own, William Smith, with a long array of British names, many of them those of our contemporaries, standing pre-eminent in the list), has led to the full establishment of those magnificent views of the history of our globe which are embodied in our articles 9 and 10.

(110.) In traversing a country in a direction always perpendicular to the lines of demarcation of its geological districts, then, it is found, as a general fact, that we always come upon the strata in a determinate order of succession, which, taken in one direction, leads ultimately up to a district or mass of unstratified rock, through a series whose fossils differ more and more from the existing organisms; or in the other, to one bearing evident marks of recent origin, *the fossils it contains imbedded* being the remains of organized beings now existing, and the material wanting in that solidity and cohesion which indicate age, pressure, and the action of heat. The series of stratified rocks, then, *reposes on* the unstratified, and to this no exceptions are found (or extremely rare ones), except in cases where volcanic action has poured out liquid matter over or among the others, which has cooled into rocky masses.

(111.) Assuming the horizontal deposition of each stratum in its origin, inclination is in itself evidence of subsequent disturbance; and when we find, as a general

rule, that the lower the strata in the order of super-position, the greater the disturbance of this kind they have undergone, those in the immediate vicinity of the unstratified rocks being often vertical, much shattered and contorted, and even, in some few cases, actually overturned or doubled back; and that upon the broken edges of these, others have been deposited horizontally, and these again disturbed, though in a less degree: the conclusion is irresistible, that it is to the intrusion from below, and forcible upheaval, at successive intervals, with intervening periods of repose, of the unstratified masses, that the disturbance has been owing, and the whole series raised from the ocean bed, not merely to its present level, but to such a level as to admit of the upper portions of the upheaved strata being subsequently degraded and carried away, so as to leave the land as we now find it. Were it not for the evidence these facts of universal occurrence afford, and for the additional proofs afforded by the corroborative one, that in every case where a section can be observed or concluded on *both* sides of a central mass of this kind, the strata succeed one another in the same order outward, and "dip" everywhere *from* the central line, we might hesitate to accept, so far as these rocks are concerned, the position of their upheaval. But when we come to look upon them, not, indeed, as the *prima mobilia*, but at least as the instruments, the levers and wedges with

which the real *primum mobile*, the central heat, does its rough work on the crust of our globe, they lose their claim to this ideal permanence, and come to be considered as, in fact, *newer* than the rocks they penetrate and displace.

(112.) We must refer to works especially treating of Geology, and, *inter alia*, to the article on that subject in the Encylopædia Britannica, for an enumeration of the long series of strata interposed between the granitic and other unstratified rocks, and the last-deposited alluvium, as well as for an account of their characteristic fossils, in detail. There is probably no part of the world in which all, or even the major part of these strata, exist actually superposed. The series is for the most part broken by the absence of many of its members; necessarily so, indeed, since what was covered with water during one epoch, and therefore a receptacle for the deposit proper to it, became dry land during another, and therefore ceased to receive such as were then elsewhere in process of formation. But the order is never inverted. The beginning, middle, and end of each form of organic life can be traced: one form, indeed, overlapping another, but once extinct, never reappearing in the formations of a later epoch. By a singular felicity, which has influenced more than anything the progress of geology, the British Islands afford, condensed into a small compass, the nearest approach to a complete

series of the strata which probably exists anywhere, and within their area (active volcanic agency excepted) there is hardly any form of geological upheaval and dislocation which is not exemplified, the Isle of Wight being especially remarkable as an instance.

(113.) Without going into detail, however, it will be advisable to give here a very brief summary of the principal *groups* into which geologists divide the strata, and their distribution. These are—1*st*, The older Igneous formations, consisting of Granite and Granitoid rocks, such as Syenites, Porphyries, etc., in which no trace of any schistose or stratified structure is discernible. 2*d*, The Crystalline Schists or Metamorphic Rocks, such as Gneiss, Mica slate, Quartzite, Serpentine, etc., in which a tendency to cleavage, or to a fibrous structure, is for the most part perceptible—arising, as Professors Tyndall and Sorbey have rendered very probable, from pressure, prior to consolidation, giving parallel directions to particles of mica, and which cause has certainly produced the "slaty cleavage" in the true slates. These rocks contain no fossils, and, as Sir C. Lyell supposes, have been subjected to a heat so near to fusion as to obliterate any vestiges of organic life they may have once contained. 3*d*, The Lower Palæozoic or Silurian system of Sir R. Murchison, in which the stratification is evident, and the earliest vestiges of life are found—mainly fishes, molluscs, and zoophytes. In these, too, and in the

metamorphic rocks, the principal metallic deposits occur. *4th*, The Upper Palæozoic, subdivided into the Devonian or Old Red Sandstone, the Carboniferous and Mountain Limestone, and the Permian or Magnesian Limestone, with the Lower New Red Sandstone. In this series fossils are abundant, and it derives immense importance from being the seat of the coal measures in every part of the world. *5th*, The Mesozoic group, comprising the Lias and Oolites, the Muschelkalk and Keuper, the Jura Limestone, and the Chalk, comprehending, as their highest member (or the lowest of the next succeeding group, according to more recent authorities), the Nummulite Limestone. *6th*, The tertiary deposits, divided by Sir C. Lyell into Eocene, Meiocene, and Pleiocene, as indicating three stages of progress towards the now existing species of organized beings. To these have been subsequently added, under the continually increasing demand for nicer discrimination in respect of era, and as the immensity of time embraced by geological epochs has gradually opened out to our view, the Pleistocene and even the Postpleistocene, the latter forming the transition to—*7th*, The Alluvial and Boulder formation, consisting of modern detritus and erratic matter. *8th, and lastly*, The Volcanic or Newer Igneous formations, trap, basalt, etc., which occur indifferently in every part of the series.

(114.) The proportions in which these several "forma-

tions" occupy the area of the existing land, is very different. The older igneous rocks, granite, syenite, etc., occupy but a comparatively small aliquot part of the whole surface, and in masses of little continuity, as might naturally be expected, when it is considered that it is only when actually thrust through the whole series, so as to tower above them all (as in some of the highest peaks of Mont Blanc), they would of themselves come into view, and that in all other cases they would only be laid bare by the destruction of the whole superincumbent series. In only a few districts in Europe are any extensive continuous granitic formations disclosed; such as in the north-west of Portugal and the south-west of Spain (if the whole of what is laid down as such in maps be really granite)—in the interval between the Bug and Dnieper (in Volhynia, Kiew, Podolia, and Cherson)—between Dresden and Görlitz—in the Grampian mountains in Scotland—the Lofoden Isles on the coast of Norway—in Corsica and Sardinia, etc. The southern chain of the Ural Mountains is also granitic; and across France, the district running south-west from St. Malo and Ushant towards Avignon, the granite occurs in frequent masses, their line of direction, when continued, passing through Corsica and Sardinia. Indeed there is hardly any extensive region of the globe in which, here and there, a granitic mass does not break forth. Along the east coast of Brazil there is a con-

tinuous granitic band from Rio to the mouth of the San Francisco River.

(115.) It is otherwise with the Metamorphic group, comprising the gneiss, mica slate, etc. These cover large and continuous districts, as, for instance, in Europe, nearly the whole extent of Sweden, Lapland, and Finland, except a narrow belt on the Baltic coast, almost the whole coast of Norway; nearly all the northern half of Scotland, from Perth northwards; nearly all the higher Alpine district of Switzerland and Tyrol, from Grenoble to Gratz; all the crest line of the Ural chain of mountains; probably the whole of Greenland, Labrador, and all the land north of Hudson's Bay; all the southern portion of Canada and the British North American possessions, up to the chain of lakes; and the Arctic sea-coast as far as the Coppermine River, the whole of Russian America, as well as the eastern corner of Asia, as far as the river Kolyma. Proceeding southwards, we find nearly the whole of Tartary, a great part of China, the Malayan and much of the Cambodian peninsula; the southern part of the peninsulas of India and Arabia; nearly all that is known of Southern Africa, up to the Deserts, with exception of the Cape Colony; and in South America nearly all Brazil, Guiana, and a considerable portion of Venezuela, on the eastern side, and the chain of the Andes on the western, occupied with this most widely distributed and impor-

tant formation, which, in effect, includes within its range almost all the highest mountains and most elevated country in the globe. Nearly two-thirds of the interior of Australia, also, would appear, so far as our information goes, to be occupied by it—so that at least one-third of the total surface of the land consists of this formation.

(116.) The next formation in point of extent, as it is in order, is what has been termed the Transition Series, comprehending the whole of the Silurian, and the lower portion of the fourth or Upper Palæozoic group, as far as the carboniferous limestone. Its greatest development is in the northern portions of the continents, extending over the major part of European Russia up to the Ural, over the basins of the upper Irtisch and Yenesei, north of the Baikal Lake, together with the district occupied by the Stanovoi, Ourakantsha, and Altai Mountains, in which the Kolyma and Indigirka rivers take their rise. The comparatively small portion of Norway which is not occupied by metamorphic rocks is filled with these strata. In our own islands they have considerable development, as well as in Portugal. In North America, they divide, with the metamorphic rocks, the whole of that immense territory east of the Rocky Mountains, with exception of a comparatively small district west of the Missouri, while in South

east side, spreading over Bolivia, and forming a belt bordering La Plata and Patagonia on the west, along their whole extent. In Australia, likewise, they occupy two such belts, parallel to one another, running along the whole east coast from the northern to the southern extremity.

(117.) The Secondary Formation, comprising the series from the Permian beds upwards, and including the chalk, viz., the Upper Sandstone, Lias, Oolite, Greensand, Chalk, and Nummulite limestone, is very much more limited in its range. It is represented in England by the chalk beds and other deposits in the south-east of the island, cut off by a line running from the mouth of the Tees to Exeter; on the eastern side by a broad belt of no great continuity, being often overlaid by the tertiary beds, but in which it is impossible not to trace a certain unity, continuing the east Anglican formation, in a direction from N.W. to S.E., over the whole of the south of Europe and the north of Africa, down to Egypt on the one hand, and over much of Asia Minor, through Arabia and Persia, into the Indian peninsula. Thence the belt (with larger interruptions) takes a northern direction, reappearing in Thibet, and again in China, in the districts of Setchuan and Hoo Quang. Again tending northwards, it reappears along the whole eastern coast of the sea of Japan, and the western of that of Ochotzk, forming the sea-bord of the Kamschatkan

peninsula. In the western continent it is much more sparingly represented, the states of Kansas and Nebraska being the only portion of North America occupied by it, while in South America it has as yet hardly been traced at all, with exception of a small district on the Orinoco River, at the northern extremity of that continent.

(118.) One of the most remarkable features of this vast formation (of its cretaceous members, that is to say), is the astonishing fact disclosed by microscopic examination, of its consisting almost entirely of the exuviæ of minute animalcules. In the Chalk, properly so called, they exist in such abundance, and of such minuteness, that millions have been reckoned to the cubic inch; and in the Nummulite limestone, so called from the shells of that name it imbeds, which forms nearly the whole of the south European and African portions of the formation (attaining, in some parts of its distribution, a thickness of many thousand feet), it consists entirely of minute foraminiferous shells, whole or in fragments; and it may be added, that the green and ferruginous sands which present themselves interposed between and underlying these deposits, have also been discovered by Ehrenberg to consist of *casts* of such shells, the shells themselves having disappeared. We have seen that in the North Atlantic, the process of the formation of such beds is still in progress, and from the bottom of the Gulf of Mexico, and the Gulf Stream,

such casts, *together with* living specimens have been brought up in sounding (Carpenter, *R. Inst. Proceedings*, March 12, 1858).

(119.) We may here recall what has been stated respecting the extensive formations of calcareous submarine masses by the labours of the coral insect. Such facts would be utterly incredible but for what we know of the astonishing rapidity of multiplication of these minute forms of animal life. Dr. Carpenter computes the progeny of a pair of aphides, if allowed to accumulate, at the end of one year, at a *trillion*. Granting the reproduction of marine animalcules to be *a thousand billion times less rapid* than that of aphides—granting that each of them, during its life time (supposed not interfered with, and food supplied), secreted only a ten-millionth part of a cubic inch of indestructible calcareous matter—we should find accumulated, in less than a quarter of a century, a globe of such material, whose diameter would exceed the distance travelled by light since the ordinarily received epoch of the creation (4004 B.C.), and the surface of the globe, supposed to continue increasing at the same rate, would then be swelling out into space a great many thousand times faster than the speed of light. There needs, then, only a residual immunity for a very small percentage of those produced to afford scope for the production of all the calcareous formations existing; and the same may be said of all

those geological formations, such as the Polishing Slate of Bilin (40,000,000 to the cubic inch!), the Infusorial formations in Holland, etc., which microscopic examination has shewn to consist of infusorial and other exuviæ.

(120.) The Tertiary formations occupy a very large portion of the whole surface of the land. They are found (as the circumstances of their deposition necessitate) occupying the intervals and hollows of all the other formations, and that, too, occasionally at such considerable elevations above the actual sea-level, as suffice to shew the enormous period which must have elapsed since their deposition. Thus, in Chile we find them at 1500 feet, in the Isle of Ischia at an elevation of 2000 feet; and in the Niti Pass, in Thibet, at an elevation of no less than 17,000 feet. In England they are not largely developed, but on the continent they form a broad belt, extending all across Europe from the Baltic to the Black sea, and including nearly the whole of Belgium, the Netherlands, Denmark, Hanover, Prussia, Poland, great part of Austria, including nearly the whole course of the lower Danube, the southern provinces of European Russia down to the Black Sea; thence entering Asia across the Sea of Azof, they occupy the whole of the Caucasian district between that sea and the Caspian, together with the depressed basin occupied by the latter and the Sea of Aral, and nearly the whole of Western

Tartary. Thence sweeping upward to the north, they cover an immense area, extending to the Gulf of Obi in length, and in breadth from the Obi to the Yenesei, that is to say, nearly the whole of Western Siberia. Southward, the Great Desert of Northern Africa would seem to belong to these formations, as well as the bulk of Arabia, Persia, and Upper India; the deserts of Gobi and Shamo are also considered as being perhaps referable to the same geological district.

(121.) In the American continent the disposal of these strata is very remarkable. In the northern continent they form a broad belt, running west of the Rocky Mountains from the Polar Sea to the head of the Gulf of California; while in the southern they follow all the sinuosities of the coast line, in a band of from 300 to 600 miles in breadth, on the eastern side of the slope of the Andes, and separated from them by the secondary belt already mentioned. The central portions of Australia, too, are probably occupied by members of this series.

(122.) Taken together, then, the Metamorphic and Tertiary strata occupy the lion's share of all the existing continents, the intermediate formations having been, for the most part, denuded from the former, while they must be assumed still to exist underlying the latter, which, from all the phenomena of their occurrence, there is little reason to doubt have been formed of the imme-

diate detritus of adjacent land during the countless ages which have been occupied in its upheaval.

(123.) The Volcanic or newer Igneous *formations* are distributed over the globe in a manner wonderfully indicative of the universality of those deep-seated causes which have produced them. They break through every other formation, not excepting the granite itself, as in the case of the Auvergne volcanoes, which, over a large district, divide the surface of the country with granite, every other formation being wanting, and whose scoriæ are found enveloping masses of feldspathic granite, torn up by them in the act of their ejection.

(124.) *Volcanoes* are either extinct or active, and either subaërial or submarine. In the former case they usually consist of cones of ashes and scoriæ (lava thrown up into the air, melted, and falling as stone in various broken and contorted forms), with a funnel-shaped depression called the crater, from which (frequently from a deep break in one part or other of the rim) lava streams have issued, coating the older layers of ashes, and binding the whole together as a mass, often intersected with dykes or vertical walls of lava. When lofty, the lava frequently breaks out laterally, and when such outbreaks are accompanied with ejections of scoriæ, lateral cones are formed, of which Vesuvius, and especially Etna, exhibit striking examples. Some volcanoes habitually pour forth torrents of lava during their erup-

tions, as Hecla, Vesuvius, Etna; others chiefly scoriæ and volcanic dust, as those of Sumatra, Java, etc.; others mud, as often happens in the eruptions of the South American volcanoes, and one (the double crater of Mowna Roa and Kirauia in Owyhee) offers the phenomenon of two perpetual seething cauldrons of liquid and red-hot lava, occasionally overflowing, but never ejected with violence. The lavas of modern volcanoes differ much in character, but are seldom or never columnar or basaltic.

(125.) Extinct volcanoes often exhibit every appearance of active ones, except their activity. In Auvergne, and the adjacent volcanic districts of France, we find cones (as that of Ayzac) which, but for the trees growing in the crater, might have been supposed in eruption not many years ago, pouring out lavas beautifully columnar; others, as the Puys of Clermont, with the craters more or less rounded off by weather, but still quite distinct, and the lava currents flooding the surrounding country; others, again (as that of Agde), water-washed heaps of scoriæ. Over many vast tracts of country deluges of lava (as in the Vivarais, and Cantal, in France) have flowed, taking a perfectly level surface, like a sea, and, therefore, evidently from a subaërial source; in others (as in the valley of Fassa in Tyrol), vast subterranean upwellings of augitic lava of inky blackness have upheaved whole provinces of pure white limestone, and

by some process of sublimation, while splintering them into the most picturesque pinnacles, have, at the same time, impregnated them with magnesia, converting the limestone into dolomite. Others, again, have broken out, and still occasionally break out; as at Santorino, Pantellaria, Sabrina (Azores), beneath the sea, and have either, after a brief appearance, been washed over and obliterated, or remain as permanent insular craters, of which innumerable instances occur—Teneriffe, Mowna Roa, Jan Mayen's Island, the Peak of the Azores (El Pico), the Isle of Bourbon, etc.

(126.) The quantity of material ejected by volcanoes in eruption is sometimes very enormous. In those of Tomboro, in Sumbawa, in 1815, ashes and scoriæ were thrown out sufficient to form three mountains equal to Mont Blanc, or to cover the whole of Germany two feet deep. The lava which streamed, in 1783, from the Skaptar Jokul, in Iceland, has been computed, on Sir C. Lyell's data (Geol. i. 375) at 21 cubic miles, a quantity equal in volume to the whole of the water poured by the Nile into the sea in a year.

(127.) The most striking features connected with the exhibition of active volcanoes, are 1st., *Their tendency to a linear arrangement when insular.* Of this, there are many very striking examples. Thus, in the Aleutian Islands, from the extremity of the Peninsula of Aliaska to the Island of Ostrova Semisopothnia. twenty-three

active volcanoes lie almost precisely in a right line, 900 geographical miles in length. The disposition of eleven active vents, which with many extinct ones, form the Kurile Islands, 600 geographical miles from the extremity of Kamschatka to Yesso, is also almost an exact right line, which might be prolonged 540 geographical miles northward, by taking in those of Kamschatka, which are obviously a continuation of them. Those of the Ladrone Islands, again, form a straight line, 420 geographical miles in length; and the linear arrangement of those of Java, Sumbawa, and Floris, over a length of 1080 geographical miles, is not less exact and characteristic. *2dly, Their constant association with coast-lines,* which is so marked a character, that hardly more than one or two tolerably well authenticated instances have been produced (and those in regions never visited by European travellers) of volcanoes habitually active, occurring at a distance greater than 300 miles from the sea. These are the volcanoes of Peshan and Ho-tcheou, in the Thian Shan Mountains, which the Chinese annals (cited by Humboldt) describe as having been so within the period they embrace; and one on Lake Alakul, whose activity within the memory of man has been rendered very questionable by the recent explorations of Mr Atkinson (*Oriental and Western Siberia*, p. 562). Mount Demawend, in Persia, indeed, is considerably more remote from the ocean; but it is on the borders of

the Caspian Sea, in the prolongation of the great Mediterranean fissure, and at the very extremity of a broad belt of volcanic activity, now for the most part extinct, which, commencing with Iceland, extends through Britain, France, Southern Europe, and Asia Minor, skirting the Mediterranean, the Euxine, and the Sea of Azof, which, there is every reason to believe, at no very remote period, to have been connected with the Caspian.

(128.) The number of volcanoes certainly known to have been in activity within the last 160 years amounts, according to Humboldt, to 225, and the total number of volcanic vents, extinct and active, to 407; but the real number is probably much greater. M. Junghuhn enumerates 19 volcanoes in Sumatra, and 45 in Java; and according to M. Laugel (*Rev. des Deux Mondes*, xiii. 353), there are no less than 900 in the vast archipelago extending round Borneo from the Nicobar Islands to the Philippines.

(129.) Besides volcanoes ejecting scoriæ and lava there occur, sometimes separate, sometimes associated with the former class, mountains evidently of igneous origin, but of which the material (trachyte, domite, etc.) has apparently issued from the earth in so imperfect a state of fluidity as *not to run*, but to form rounded masses, sometimes of great height. The Puy de Sarcouy, in the chain of volcanoes at Clermont, is a very characteristic specimen; and the Puy de Dôme itself consists

of this material, and does not appear ever to have been, properly speaking, *in eruption.*

(130.) By far the greater number of volcanoes, and of the active ones an immense majority, occur upon the coast-line of the Pacific, regarded as prolonged by the chain of islands and the Australian coast down to Van Diemen's Land and New Zealand, and even to the active volcanoes of Mount Erebus, and the extinct one (?) of Mount Terror, in South Victoria. Thus viewed, indeed, the Pacific may be considered as bordered by an almost continuous line of recent and extinct volcanoes, and of igneous rocks, clearly owing their origin to volcanic action. Along the whole chain of the Andes, in Central America, and in Mexico, almost all the loftiest peaks are volcanic or trachytic, and the earthquake and eruption are normal, and not exceptional events. Along the north-west coast of the American continent, the chain of newer igneous formations is almost continuous, and in Oregon attains an immense development; nor are active volcanoes of great magnitude wanting, *but only those parts of the volcanic zone which lie upon the coast-line* contain such, viz., Mounts Regnier and St. Helens, at the mouth of the Columbia River. The line is continued along the coast of Russian America by the Cerra de Buontempo, or Mount Fairweather (14,710 feet) Mount St. Elias (17,850 feet), and Wrangel's Volcano (N. lat. 62°), in Russian America. From almost the

extreme west point of the American continent, on the Aliaskan peninsula (which is igneous), the chain is continued to Kamschatka by the Aleutian Isles, where eruptions are frequent, and a new island rose in 1814, and thence, in almost unbroken succession, by the Kurile and Japanese Islands (where outbreaks are frequent and of excessive violence) through Formosa and the Philippines down to the Indian Archipelago, where Sumatra, Java, Sumbawa, and Floris, exhibit a perfect rookery of volcanoes, the scene of one of the most dreadful eruptions of modern times (that of Tromboro, above noticed).

(131.) The east coast of Australia offers no active volcano, but it is marked along its whole extent, from north to south, with evidences of former igneous activity, occurring (in striking resemblance with what prevails on the opposite coast in South America) among the crystalline and transition rocks which constitute the general sea-bord. But the subterranean fires would seem here to have shifted their ground, and taken up new line of action to seaward, at an interval of from 1000 to 1200 geographical miles from the coast, but still conforming to its curvature, prolonging the series through the Solomon Islands, New Hebrides, and Friendly Isles, to New Zealand.

(132.) It seems impossible to disconnect this obviously systematic arrangement with the general evidence

have subsequently become a habitual volcanic vent, as in the case of Teneriffe and Vesuvius, where the remains of the old crater or broken dome still exist, partially surrounding and inclosing the modern cone.

(135.) *Mean elevation of the Continents, Level Lines, Lines of greatest and least Declivity, Valleys and Ridges, Lakes, Drainage Basins.*—Barometrical observations, both stationary and itinerant, assisted of late by that very useful and portable form of the barometer called the aneroid, which can be read off in a carriage or on horseback, have been now so far extended over the whole accessible surface of the globe, as to afford ground for a reasonable conclusion respecting the average elevation of the surface of the land above the sea-level, and a very accurate one as to those of mountain chains and summits. The conclusion arrived at is not a little remarkable, and quite contradictory to former impressions. The mean height of the surface of the dry land most probably does not exceed one-fifteenth of the mean depth of the bed of the ocean. The following are given by Humboldt as the approximate heights of the centres of gravity of the continents above the sea level, viz., Europe 671 feet, Asia, 1132, North America 748, South America 1151; from which it follows that the mean elevations of their *surfaces* (the doubles of these) are respectively 1342, 2264, 1496, and 2302 feet. Africa, from what we know of its interior, with the additional

light lately thrown on it by Dr. Livingstone, is probably intermediate between Europe and Asia, and its mean height may therefore be reckoned at 1800 feet, so that a general average of the whole would give about this last-named height for the mean height above the sea-level of the surface of the whole land. A rise of the ocean level, therefore, to this extent would submerge at least three-fourths of the existing area of the land. It is remarkable for how moderate an item the great mountain masses of the world figure in the general result. The Alps, spread equally over the surface of Europe, would raise the general level no more than 21 feet (Humboldt); and the vast mountain chains of Asia, so treated, would afford a superstratum of only 150 feet thick over that continent (Ansted), the elevated desert of Gobi, 128, and the whole plateau of Thibet, with its flanking chains, 358.

(136.) If we suppose a series of level lines marking out elevations above the sea, rising progressively by steps of 100 feet, these of course would be the coast-lines of the land left outstanding were the sea to rise by such successive degrees; and if we suppose the same continued below the sea-level we should in like manner obtain the depressed coast-lines. Thus we should cover our chart of the world with a series of re-entering curves or ovals, more or less complicated, each summit and each cavity being surrounded by a series of its own—the one series expressing a mountain, the other a basin.

Where the same level line makes a loop by crossing itself (at what may be termed a jugal point [*jugum*], we have a *col* [*collum*] or mountain-pass *across* which lies the lowest, shortest, and steepest course by which it is possible to pass out of one basin into another, or from one branch of a basin to another branch, and *along* which is the shortest, highest, and least inclined path from summit to summit.

(137.) Two descriptions of lines intersect the level-lines of a country at right angles, viz., lines of water-sched (wasser-scheide, separation of the waters not water-*shed* the slope *down which* the waters run), or ridge-lines, and valleys or river-courses. The former, in proceeding downwards from a summit, intersect the level-lines at their convexities or greatest horizontal distances from the summit, and are, consequently, the paths of gentlest declivity, or the longest lines of descent from a higher to a lower level. The latter intersect them in their concavities, or least distances, and are the lines of greatest steepness or swiftest descent, and, of course, those chosen by streams whose erosive action is perpetually deepening them. Where the bottom of a basin lies above the sea-level, or, if lower, is separated from the sea by inclosing ridge lines, it becomes filled, wholly or in part, with water, and constitutes a lake, with or without an outlet. If wholly, the water finds a vent at the lowest jugal point or lip, and the lake

becomes a feeder of a river, or in some cases of several, issuing by distinct outlets, as in the instance of the Lake of Yojoa in Honduras (Squier). In this case its supply exceeds its evaporation. In the contrary case, the area occupied by the water adjusts itself so as to effect an equilibrium between the evaporation and supply. The former case is that of infinitely the most common occurrence, and lakes thus fed from a number of upland sources, to which they serve as reservoirs, issue in rivers, or, if above the limit of perpetual snow, they become "nevés" in glaciers. The latter case can never happen in moist climates, since, however large the basin, and however high the lip, it must at length become filled, and overflow; but in arid regions, especially in very elevated districts, in which the habitual siccity of the upper atmosphere* comes in aid of otherwise favourable local circumstances, it is not uncommon: as, for instance, in the Lake of Titicaca; on the lofty plateau of the Desaguadero in Bolivia, upwards of 12,000 feet above the sea; in the Salt Lake of Utah, on the elevated region north of Mexico; in the Lakes Tchad, 'Ngami, and Nyassi, in Africa, etc. But the most remarkable instance of such a "continental basin," or one in which all the waters run inwards, terminating in inland seas and salt lakes (for, owing to the perpetual concentration of the drainage water by evapo-

* See an Essay on METEOROLOGY by the Author, art. 88 (A. & C. Black).

ration, such inland collections of water are of necessity more or less salt), is to be found in the great continental basin of Central Asia, an area of nearly 3,000,000 square miles, which includes the Caspian Sea, the Sea of Aral, and a vast multitude of inland rivers of all magnitudes which feed them and innumerable other salt lakes, such as the Lakes Van and Urumiah in Armenia, the Lakes of Balkasch, Issikul (or Touz), Alakul, and Kezilbasch, in Turkistan, the Lake Lob or Loph in Upper Tartary, etc. etc. Of these, some are situated on elevated plateaus, but the Caspian and Aral Seas are situated in an extensive depression, an area of several hundred thousand square miles in extent, actually below the sea-level, the surface of the Caspian itself being 84 feet below the Black Sea.

(138.) A still more remarkable instance of depression below the sea-level, and consequent internal drainage, resulting in a lake of almost saturated brine (which is also the case with that of Utah), is that of the Dead Sea, in Palestine, fed by the River Jordan, the level of whose surface has been satisfactorily proved to be no less than 1312 feet below the Mediterranean, from which it is separated only by a narrow belt of land, occupied by the chain of Mount Lebanon, about fifty miles in breadth. There can be little doubt that the Jordan at some former period flowed into the Gulf of Akabah, in the Red Sea, and its course being depressed into a deeper valley, or

the connection cut off by some geological change elevating the southern part of the valley; the sea-water continued to occupy this basin, which, when the gulf in question filled the valley, extended to the Lake of Tiberias, the surface of which being 983 feet above the Dead Sea, its salt water has been all washed down into the latter by the river flowing through it. Such a barrier once in existence, the increasing specific gravity of the water would counteract the effect of subterranean percolation from the Mediterranean (Fox). The waters of the Dead Sea have a specific gravity of 1.24 (Marcet), so that were a narrow channel of communication opened at a depth of about 7670 feet below the surface of the Mediterranean, the two seas would remain *in equilibrio* by equality of hydrostatic pressure.

(139.) In the upheaval of any extensive tract of land from the sea, hollows fitted for lake basins cannot fail to be left. If the upheaval be rude and paroxysmal, resulting in the formation of mountain chains, and accompanied with fracture and dislocation of the strata, such hollows will be deep, precipitous, and narrow in proportion to their length. Such is the general character of the lakes in mountainous regions—of the Swiss lakes, for instance, those of North Italy, of Cumberland, Westmoreland, and Scotland, etc. On the other hand, where the upheaving forces have acted more gently and gradually, and have raised the country with more uniformity,

producing extensive plains and low steppes, lakes will not only be more numerous, by reason of the less erosive power of running water to drain them by deepening their outlets, but will affect more rounded forms, and cover the country with shallow pools or ponds void of all picturesque beauty, as we see exemplified in Poland, and in the districts between the Gulf of Finland and the White Sea, which are almost connected by a great chain of shallow lakes, some of them (as those of Onega and Ladoga) very extensive. Occasionally, too, lake basins come to be created by what may be called accidents, as by volcanic ejections barring the courses of rivers, as in the instance of the Lake of Aidat, near Clermont in France, produced in this manner by the lava of the Puy de la Vache damming the river Sioule.

(140.) Every line of watersched continued downwards terminates either in a lake or in the sea, and always (of necessity) in a promontory, or more or less projecting tongue of land, or salient point of coast line. The area, bounded on the land side by one continuous line of water-sched, and to the seaward by the sea itself, constitutes the drainage basin of whatever river flows into the sea between its extreme promontories.

(141.) The river courses and water-sched lines then form a double system of allineations, the one branching out from the lowest cavities or pits, for the most part concealed below the sea; the other from the mountain

summits. As the river branches can never be traced up beyond a certain degree of minuteness, nor the ridge lines below the sea level, these two systems have no common points, the fibres of one being always interposed between those of the other, so that, in the absence of one system of lines on a chart, it can always be approximately traced if the other be correctly mapped; and thus the limits of basins of drainage admit of being assigned, and the area of a country divided among its several rivers, the courses of rivers being generally much better laid down than the mountain system of a country. For a list of the superficial extent of the basins of the principal rivers of the world, according to the best authorities, as at present known, and the lengths of their main streams, see Appendix.

(142.) *General Distribution of Mountains.*—When we cast our eyes on a complete and well-executed set of charts of the mountain systems of the world, such for instance as those in the Physical Atlas of Mr. Keith Johnston, it is impossible not to be struck with the contrast exhibited between those of the New and Old World. In the former, besides a general direction of the great mountain chains approximating to a meridional one, we find a continuity, unbroken except in a few small intervals in the narrow isthmus connecting the two Americas, of a vast and extremely precipitous line of very elevated mountains, running from the

Arctic Ocean almost to the extremity of Patagonia, including 120° of latitude, or 7200 geographical miles (8280 statute miles), skirting along the western coast of that immense continent, closely following all its flexures in the southern half; and in the northern, opening out somewhat more, it is true, in breadth, and decreasing in average height, but still preserving the same general character of a lofty mountainous western border to a vast expanse of eastern lowlands. And throughout the whole extent of this border, we perceive a most distinct and unmistakeable tendency to a system of double or triple ridges nearly or exactly parallel, not here and there for short distances, but extending for hundreds of miles in succession, and resumed again and again when interrupted. In the Old World, on the other hand, we find no single well-defined continuous chain running throughout, much less following the coast line, but a broad belt of mountainous country traversing the whole mass of land in a general direction nearly at right angles to the meridians, and carried through the heart of the continents, from the extremity of Europe and North Africa across to the western shores of the Pacific. In the European portion of this system, linear prolongation, except in the Pyrenees, is very far from distinctly indicated. On the contrary, divarication and embranchment are there the dominant features, as they are especially so in the north-eastern region of Asia; and it requires

some determination in tracing connections, to follow out a leading line through the Pyrenees, the higher Alps, the Caucasus, and the mountains of Elbrouz, through the Hindu Koh, up to the great system of Asiatic mountains which enclose the plateau of Thibet. Neither is the principle of parallel association carried out with anything like the same precision and sequence in the old as in the new continent. Along the Caucasian and Elbrouz range, and as far as the termination of the Hindu Koh, this principle is pretty clearly maintained; but from the point in Little Thibet, where this last-mentioned system forks out into the two great chains of the Himalaya and the Kuen Lun, which enclose the table-land of Thibet Proper, a greater degree of interlacement and confusion prevails, and beyond the termination of these ranges in Assam and on the Chinese frontier, the mountain system of China and south-eastern Asia spreads out like an immense fan, in some of whose ranges a high degree of parallelism is preserved among contiguous members, while in others the branching character prevails quite as conspicuously.

(143.) *Mountain Systems of America.*—In describing more particularly the several partial systems of which these great subdivisions consist, we shall begin with the more simple—that of the new world. Commencing with the very extremity of the southern continent, or what may be considered its natural prolongation, the

Terra del Fuego, we find already a most rugged country, with lofty peaks, and glaciers descending from them, one of which, "Mount Sarmiento," attains the elevation of 6900 feet. On the main land, though it can hardly be said that a continuous mountain chain borders the whole of Patagonia, we find lofty single peaks, such as "Mount Stokes" (6400 feet), a country generally mountainous, and an excessively rough and broken coast, full of fiords like those of Norway, of immense depth, fed by glaciers descending from the high lands above—the perpetual snow-line here descending as low as 3000 feet above the sea-level. This, however, does not prevent a great luxuriance of vegetation below that limit, the extreme humidity of the climate favouring the growth of forest trees, which clothe the mountains from the coast upwards. What may properly be called the Cordilleras, commence in latitude 47½°, about the Gulf of Penas, and extend thence close to the coast line to Mount Llebecan (latitude 41°-45°), including volcanic peaks such as Yanteles (8030 feet), Corcobado (7510), and Minchinmadava (8000), already entitled to be regarded as lofty mountains. At this point the broken coast-line and its complicated insular barrier ceases with the Isle of Chiloe, or rather the same system of formation is continued on the mainland by the addition of a bordering belt between the Andes and the sea, terminated in a granitic rocky barrier skirting the Chilian coast. Here

the Patagonian Andes terminate, and the Chilian commence; and from this point we find, interposed between the cordillera and the sea, a slope of land continued up to the equator, nowhere exceeding 120 geographical miles in breadth from the coast to the actual ridge. Hence, too, the chain itself gains a great accession of height. Already at Valparaiso occurs the gigantic porphyritic peak of Aconcagua, the loftiest of the whole chain (23,910 feet); but the chain continues single (with a slight appearance of lateral parallels in the Sierra de Velasco, and the Pamatina ridge, at 75 and 100 geographical miles respectively distant eastward from the main chain) till it reaches the 20th parallel of S. lat., where the Chilian Andes terminate, and the Bolivian commence. Along their whole extent the summits of the former range attain and surpass the snow-line, which rises rather suddenly from 8000 feet at Valdivia, in lat. 40° S. to 12,780 at Valparaiso (33° N.), between which, about the parallel of Concepcion (36° 40′ S.), a corresponding change of climate from extreme moisture to excessive dryness (a consequence of the change of prevalent winds), takes place, and furnishes a satisfactory explanation of the phenomenon.

(144.) About the 20th parallel, near a point marked by the lofty volcanoes of Gualatieri (21,960 feet), and Sahama (22,350), the chain which had so far followed a precise meridional direction, deflects to the N.W., still

accompanying the coast line; but it is now flanked eastward by a great parallel chain, the Cordillera Real, commencing at Potosi, the highest city in the world (being 13,350 feet above the sea), and near which, at a level of 16,150 feet, is one of the richest silver mines known. These chains include between them the Plateau of Bolivia, a great table-land upwards of 130,000 square miles in extent, and 12,700 feet above the sea level, forming the internal drainage-basin of the Desaguadero, in which is placed the lake of Titicaca, already mentioned, and which is part and parcel of a considerably more extensive "continental basin," of which more hereafter. The chain of the Cordillera Real is also extremely lofty, and full of high peaks and ridges, among which the non-volcanic mountain of Illimani attains an elevation of 21,150, and that of Sorate 21,290 feet. It pursues its parallelism with the main chain (in which alone the great volcanoes and domelike trachytic igneous mountain-masses occur, and in which are the active volcanoes of Arequipas (20,320 feet), Uvinas (16,000), Viejo (20,500), and Chipicani (19,745), up to the knot of Pasco, a great ganglion, as it were, of the system, in lat. 10° 42′ S., and excessively rich in silver mines, from which point springs a third chain, preserving like the other two, a strict parallelism with the coast line, from which it is distant 450 geographical miles, and running N.W. for about the same distance, the three being known

as the eastern, central, and western Cordilleras of Peru.

(145.) From the termination of this triple arrangement to the equator, and somewhat beyond, the Cordillera is continued in a double line, or rather in a series of pairs of parallel ridges about thirty miles asunder, separated by cross ridges, and placed exactly conterminous; in the northern part of which are situated the great volcanoes of Chimborazo (21,424 feet), Cotopaxi (18,875), Antisana (19,137), Pichincha (15,924), and Tunguragua (16,424), a group unequalled in the world. These enclose the elevated valley of Quito, about 200 miles in length, with a mean elevation of 10,000 feet. The city itself is 9543 feet above the sea, and contains, or once did contain, 70,000 inhabitants.

(146.) The equator passes across the Nevada of Coyambé, a beautiful snow-clad cone, not volcanic (at least not active), of 19,535 feet in height, and immediately north of it, the phenomenon of a triple, and nearly parallel mountain-chain is resumed—those of the eastern, central, and western Cordilleras of Peru. In the *central* Cordillera occur the great volcanoes of Puracé (17,034 feet), and Tolima (18,020).

(147.) It deserves especial remark, that the most westerly of these chains does not continue as a lofty mountain-range into the isthmus of Panama, but dies out in a succession of low, nearly parallel ridges;

while the eastern, deserting its parallelism, curves round, with a circular sweep, to the eastward, and forms the littoral chain of Venezuela, terminating in the peninsula of Paria, or prolonged into the Isle of Trinidad. The Sierra Nevada of Santa Marta, near Cape St. Juan, on the Caribbean Sea, 19,000 feet in altitude, may be considered as an outlying prolongation of the middle chain. Whatever the forces which have elevated this vast mountain system, and however they may stand in connection with those which, probably at a much earlier period, have raised the chains north of the isthmus, there is evidently a breach of continuity, or at least a diversion of activity at this point.

(148.) The Andes, from their very commencement in Patagonia, slope rapidly, but not precipitously, to the eastward by a series of terraces consisting of secondary strata, which run out to no very great distance from the chains themselves, and terminate in the vast expanse of low country occupied by the tertiary formations, and by the alluvia marking the lower courses of the great South American rivers. The closed area or continental basin spoken of in art. 144, extends on the east side of the loftiest chain, from lat. 14° 10′ to 30° 40′ S., or about 1600 geographical miles in length, with an average breadth of 120 geographical miles, comprising an area of nearly 200,000 square geographical miles, and contains, besides the lake of

Titicaca, several other smaller lakes, which are salt. This basin may be considered as occupying two distinct levels; the surface of Titicaca being more than 12,000 feet above the sea, while the southern portion of the basin (if indeed it be really such, which seems a little doubtful) has a much lower altitude.

(149.) The *mean* elevation of the South American Andes, according to Humboldt, is 11,830 feet, and the extent of surface covered by their bases is 531,000 square geographical miles. They present the extraordinary phenomenon of great communities of men, subsisting in wealth and comfort, at an elevation at which the inhabitant of the plains finds respiration difficult. Besides Quito, the city of Cuzco, on the outer and northern edge of the Bolivian plateau, at an elevation of 11,384 feet, and once the capital of the Incas, and the seat of an early and high degree of civilization, still contains 50,000 inhabitants; and the silver mines of Pasco, at an elevation little inferior to those of Potosi, attract into their neighbourhood a numerous and active population.

(150.) The narrow isthmus which connects the two continents, under the general appellation of Central America, preserves the character of precipitous descent to the sea on its west side, and is studded along the coast of the Pacific with volcanic mountains broken into groups, and intermixed with masses of disconnected

table-land. The principal of these groups are those of Costa Rica, known as the groups of Uragua and Salamanca, succeeded by a great chain of volcanoes along the west coast of Honduras, Nicaragua, and Guatimala, among which are those of Agua, 15,000 feet in height, and Cosiguina, which, though less lofty, became in 1835 the focus of a frightful eruption, the ashes of which were carried even to Jamaica.

(151.) Entering upon the North American expansion of the isthmus, we find in Mexico a singular volcanic group extending almost precisely east and west, and from sea to sea, consisting of very elevated mountains, viz.—Colima (12,000 feet), Toluca (15,542), Popocatepetl (17,717), Iztacihuatl (15,705), Orizaba (17,374), and Tuxtla. With these the active volcanic series seems to terminate, and what may be called the regular mountain system of North America to commence. Indeed this line of volcanoes seems scarcely to belong to the coast chain, but to be of later origin, cutting, as it does, across its direction almost at a right angle, and finding its prolongation in the Antilles.

(152.) To understand the mountain system of North Western America, we must conceive two coast lines similar to that which bounds the southern continent an eastern and a western, the latter of posterior elevation to the former, and having between them the broad tertiary area noticed in art. 121. The former of these is

marked out by a system of mountain chains, running generally northward, but converging towards a central knot or ganglion, about the 40th parallel of latitude, near the sources of the Arkansas river, and at a point, at present of some political interest, as affording almost the only practicable access from the east by rugged and difficult passes to the Mormonite settlement of Utah. These branches, of which the principal are the Cordillera of Cohahuela and San Luis de Potosi on the one side, and the Sierra Madre prolonged into the Sierra de S. Juan and the Sierra Verde on the other, enclose and sustain between them the high table-land of Mexico from 6000 to 8000 feet above the sea (Mexico itself is 7482 feet), and on the eastern side slope down to the flat country by two great terraces of 4000 and 2500 feet average respective elevation, occupying the eastern portions of Texas and Kansas, a country of exceedingly sterile and uninviting character. From this knot or ganglion, marked by high elevations, lately become known as Long's Peak and Pike's Peak, and by the broken ranges of the Bow Medicine mountains, between and across which the direct railway route to California from the east may one day come to be traced, the main chain of the Rocky or Chippewyan Mountains is continued in a N.W. direction in a straight and almost unbroken course to the mouth of the Mackenzie River in the Arctic Ocean. It is generally lofty, and contains

several very high peaks, such as Fremont's peak (13,568 feet), "Mount Hooker" (15,700), and "Mount Brown" (15,990) respectively, in altitude. Above the 45th parallel, however, the chain forks out and sends out a lower branch into the Columbian territory, which runs generally parallel to the main chain as far as 60° N., and between the 50th and 60th degrees is again accompanied by another parallel chain above 300 miles in length, which divides the interval between the coast line and the former chain almost equally. The distance between the eastern range of this great barrier of mountains and the Pacific varies from 300 geographical miles at its two extremities to 800, where it recedes farthest inland in 40° N., and encloses the basin of Utah.

(153.) The western coast-range commences northward with Mount St. Elias (17,850 feet) in 60° N. lat., and Mount Fairweather (Cerra di Buon Tempo) (14,782), and follows the coast-line with as much fidelity as the southern Andes, never receding from it more than 150 geographical miles; and is continued under the name of the Cascade Mountains, and the Sierra Nevada, down to and along the whole Californian peninsula. In latitude 35° N., nearly opposite Point Concepcion, it sends off a branch northwards, running between the main chain and the coast mountains, about 450 miles in length, repeating strikingly the phenomenon of parallelism of which the Andes have afforded so many instances.

(154.) Between these two barriers lies a plateau of elevated land, comprising two remarkable districts—the Oregon territory, in which a vast development of volcanic activity appears, at some remote period, to have subsisted, and the great saline plateau, or inland basin of Utah, whose elevation is from 4000 to 5000 feet, and the waters of which, having no outlet, form a series of salt lakes, one of which, lying close to the settlement so called, is of considerable extent, and almost saturated with salt.

(155.) Neither the northern coasts of America nor the interior of the continent carry those outward and visible signs of violent and paroxysmal upheaval the western mountains suggest; nor do any extensive mountain ranges exist in the northern, except in the immediate vicinity of the eastern sea-bord, along the coasts of the United States. Here we find the St. Lawrence delivered into the Atlantic along a wide valley skirted on the north by the Watshisch Mountains, a range of no great elevation, extending from the north-east extremity of Labrador to the Mistassin Lake, and terracing down by two subordinate parallel ranges to the valley, and on the south by the Nôtre Dame, the Green, the White, and the Adironbeck Mountains—a series of low interrupted parallel ranges of hills, among which are some which rise to the dignity of mountains, as Mount Washington (6428 feet), and Mount Katahdin (5360 feet) in Maine, which stands out apart from the

general range. These hills are separated from the more important system of the Appalachian and Alleghany Mountains by the valley of the Hudson River, which cuts across them, and which, doubtless, at some earlier period, extended up to the Gulf of St. Lawrence, cutting off New England, New Brunswick, and Nova Scotia from the main-land.

(156.) On the southern side of the Hudson commence the mountain ranges of the Alleghanies, or the Appalachian system, a series of several closely parallel chains, much cut across by transverse valleys, affording outlets to numerous rivers running through the states of Pennsylvania and Virginia, and dividing the Carolinas from Kentucky; running south as far as the 33d parallel of latitude, and forming a belt of about 120 geographical miles in breadth, and nearly 800 in length. The slope of these hills to the sea-bord comprise some of the finest districts and the most fertile and diversified country in the United States. The ranges themselves have a mean elevation of 2556 feet, and in few places exceed 3000 or 4000 in height, and appear to have no central dominant axis of elevation, but to form an excellent exemplification of Mr. Hopkin's views of the action of upheaving force, extending over an area much longer than its breadth, which he has shewn to have a tendency to produce parallel longitudinal fissures, cut across by others at right angles to them.

(157.) The Alleghany mountain system belongs chiefly to the older and newer Palæozoic, the Silurian and Devonian groups of rocks, being flanked on both sides along its whole length by bands of the carboniferous series, which on the west expand into a vast territory full of coal measures, the source of immense present and future national prosperity. Further eastward, below the carboniferous limestone, crop out belts of metamorphic and crystalline formation, preserving a parallelism with the crests of the mountain ridge on the one hand, and with the general direction of the coast on the other.

(158.) The mountain systems of the east side of South America differ from those of the northern continent, in consisting almost entirely of metamorphic and crystalline rocks; and from that of the western coast in exhibiting little of that systematic tendency to parallel arrangement (except along the coast of Brazil) which is so conspicuous a feature of the latter. They form two distinct systems, that of Parimé and that of Brazil.

(159.) The mountain system of Parimé occupies an area from a little north of the equator to about 8½° N. latitude, and from the 50th to the 60th meridian of west longitude, comprising the whole district of Guiana between the mouths of the Amazon and Orinoco, and forming the watershed between the lower portions of the basins of other great rivers. It consists of a plateau of from 1500 to 2000 feet in height, of granite and crys-

talline rocks, and rises to a series of mountain chains variously directed; those known as the Sierras of Imaraca, Pacaraimo, and the long southern boundary of the district (Sierra de Acaray, Triputa, or Tamucaragua), running nearly east and west, while the more westerly members of the group (the Parimé and Maigualida Sierras) affect a meridional direction. The whole system rises like an island (as no doubt at some earlier epoch it was) from a vast tertiary district, which completely surrounds it, being, however, very narrow on the coast side, but developed inland over an immense tract. There are only two mountains in the whole formation which rise to any great elevation—that of Duida (7149 feet) at the western extremity, and Roraima (7450), near the centre of the district.

(160.) The Brazilian mountain system occupies a coast line of nearly 27° of latitude, from the most easterly projection of the continent nearly to the mouth of the La Plata, and extends its ramifications 1800 geographical miles inland, separating the waters of the Amazon River from those of the La Plata. The coast line for nearly the whole extent of this system is granitic, and a mountain barrier (under the names of the Sierras of Espinhaço, Pedade, Frios, Gran Mogol, Almas, Chapada, and Muribeca), consisting principally of crystalline rock other than granitic, upheaved by the protrusion of the latter, runs from Rio Janeiro in a north-east direction,

at an interval of about 200 geographical miles from the coast, separating the coast rivers from the basin of the San Francisco River, which runs parallel to them till it escapes through a break between the Sierras Muribeca and Caryris, between which latter and the Atlantic run two other chains, preserving an exact parallelism with it. The line of mountains is continued, as the Sierra Vermelha, diverging somewhat from the sea-line, to the north-east coast near the mouth of the Paranahyba River. The mountains of this principal barrier line are pretty lofty, attaining in the Peaks of Itambe 5960 feet (lat. 18° 40′ S.) and Itacolumi (5750 feet) (lat. 20° 25′ S.) (which gives its name to the mineral Itacolumite) and Itabira (5250 feet). The mountains of the Corcovado and the Organos, near Rio Janeiro, are remarkable for their picturesque beauty and the rich development of vegetable forms which adorn them and indeed the whole of this region, and clothe their ridges to the summit.

(161.) The interior of this mountain district constitutes a plateau of vast extent, whose mean elevation is about 3200 feet. It is intersected with chains running in very various directions. The Cordillera Grande runs for 400 geographical miles from north to south, precisely along the 50th meridian, and that of the Montes Pyreneos for 150 exactly east and west. The diamond mines of Brazil are situated on the slopes of the Espinhaço range, and the ruby, topaz, and emerald are also the

produce of the Brazilian mountains. Gold is washed down from the mountain by almost all the Brazilian rivers but it is chiefly in the province of Minas Geraes that the richest gold deposits and the finest precious stones are found.

(162.) *European Mountains.*—The mountains of Europe have been divided into six principal groups, or systems—the British, the Iberian or Spanish, the Alpine, the Scandinavian, and the Sarmatian. The mean height of the surface of Europe, as we have seen, is 1342 feet, so that an elevation of the sea level of 1000 feet would submerge by far the larger portion of it. In fact, such an elevation would insulate Scandinavia, and cover at least two-thirds of France, the whole of Belgium, Holland, Denmark, North Germany, Prussia, and Poland, together with the whole of Russia, up to the Ural Mountains and down to the Black Sea, with exception of that small and insignificant group of low hills which under the name of the Valdai, constitute the "Sarmatian System," and which suffice to afford a watersched line to the basins of the Dwina and Neva, which deliver their waters into the White Sea and the Gulf of Finland, and to determine the south-west course of those of the Dnieper and Volga.

(163.) The British system is no way remarkable for height, the highest summits in its several compartments being Ben Nevis in Inverness-shire, Scotland (4368

feet), and Ben Wyvis in Ross-shire, Cross Fell in Cumberland (3383), Snowdon in Wales (3557), and Curran or Cairn Tual in Kerry, Ireland (3410). Only along the western coast-line in England and Wales is there any considerable tract attaining 1000 feet above the sea-level, and scarcely any point of the eastern or midland counties reaches that elevation. The north-western part of Scotland beyond Loch Ness is, generally speaking, above that level; and the chain of the Grampians, which stretches across the country from N.E. to S.W., has numerous ridges from 2000 to 3500 feet in height. In Ireland there are but few points which exceed 1000 feet, and those, as in England, chiefly along the west coast.

(164.) The general direction of the Scotch mountains (which consist chiefly of crystalline rocks, with here and there, in the Grampians, true granite), as well as of the deep cleft of Loch Ness, which cuts across the country from sea to sea; and the exceedingly rectilinear character of this, and of the strike of the formations of the whole of Scotland, and especially of a great belt of trappean and basaltic formation which crosses it, from the Friths of Forth and Tay across the channel to Antrim in Ireland (where it is developed in the magnificent colonnades of the Giant's Causeway), are not among its least remarkable features. The rugged nature of the country affords, both in the west of Scotland and the north-

western counties of England, lakes and other scenery of exquisite beauty. The same character of a general north-eastern strike of the geological formations, which is supplanted in the northern counties of England and in Wales by a meridional direction of the leading eminences, re-appears over its southern and eastern portions, as well as in the great contraction of breadth in the island between the estuaries of the Severn and the Welland.

(165.) *The Scandinavian* mountain system has the same general north-eastern direction. It consists mainly in a series of lofty and broad plateaus, intersected by deep valleys cutting them down to the sea, where they form a coast-line of excessively rugged character (art. 103). The chain extends along the whole western coast of Norway, from end to end, upwards of a thousand miles, under the names of Hard-angar, of the Langefield, the Dovrefield, or Doffrines, and the Kiolen Mountains; the highest summits of which are the Schneehutten (7520 feet), in lat. 62° N., and the Sulitelma (6200), in lat. 67° 20′ N. The greatest part of them rise above the limit of perpetual snow. A considerable portion of this range consists of silurian rocks.

(166.) The *Iberian Mountain System* consists of a great rectilinear barrier (the Pyrenees), of the Permian, Carboniferous, and Devonian strata, with some granitic masses (especially towards the eastern part of the chain),

extending from the farthest western point of the peninsula (Cape Finisterre) to Cape Creux, the farthest east. It is very lofty—no less than 970 feet in mean elevation, and has several peaks exceeding 10,000 feet in height, viz., the Malahite or Nethou (11,168 feet) Mont Perdu (10,994), the Cylinder of Malore (10,899), the Maladetta (10,886), and the Vignemale (10,820). Spain itself is generally high land, having a central plateau of nearly 2000 feet in elevation. Besides the Pyrenees, it has several other mountain chains—the granitic chain of the Sierra de Guadarama (prolonged into Portugal by the Sierra Gredo which rises to a height of 10,552 feet and the mountains of Gàta, to the S. d'Estrella)—the Toledo chain, which culminates at Guadaloupe, and the Sierra Nevada, which skirts the south coast, and rises, in the peak of Mulhaçen, south-east of Granada, to the height of 11,664 feet.

(167.) The mountain system of North Africa belongs, obviously, to judge from its general parallel direction and elevation, to the Spanish group of the European formation. It consists of three subdivisions, the most extensive and loftiest of which is the most southern, and runs generally parallel to the Mediterranean coast, at a distance of from 100 to 180 geographical miles, following the curvature of the Atlantic sea-bord outside the Straits of Gibraltar, through Morocco, where it rises to the height of 13,000 feet, or above the line of perpetual

snow. This chain continues eastward to the Gulf of Cabes at the confines of Tripoli and Tunis, and would seem to be a continuation of the Apennines through Sicily. The middle range, or rather succession of terraced heights and table-lands, interspersed with mountains rising from the lesser or coast range to the interior and higher, comprises the best and most habitable part of North Africa, including Algeria, while the lesser, commencing opposite Gibraltar as an offset from the great chain, and rising there to a very considerable altitude, runs first inland, then returns to the coast about Oran, and continues along it as far as Tripoli.

(168.) The Alpine is the highest, most extensive, and most complex of the mountain systems of Europe. It connects itself with the Pyrenees, through the mountain districts of France west of the Rhone,—the Cevennes, the Puy, and the Vosges Mountains, a district generally elevated above 2000 feet, but rising to peaks of 6220 feet (Puy de Sancy), 6093 (Plomb du Cantal), and 4806 in the Puy de Dome, the mountain on which the decrease of barometric pressure was first observed by Pascal in the middle of the seventeenth century. This district, which consists in large measure of granite and crystalline rocks, is full of vestiges of most intense volcanic action, and presents, in the chain of the Puys near Clermont, in the Mont D'or, and in Auvergne and the Vivarais, multitudes of cones of scoriæ and ashes apparently quite

fresh, together with trachytic domes (Puy de Dome, Sarcouy, etc.), basaltic colonnades (of which those of Chenavari, Entraigues, Expailly, and Jeaujac are the most remarkable) and plateaus of immense extent which occur in a country of most picturesque beauty, affording the most accessible and agreeable field for the study of volcanic phenomena which Europe affords. East of the Rhone the mountains become more elevated, and through the Dauphiné and Grenoble mountains, or, as they have been called, the Cottian Alps, connect themselves with the great system of the Pennine Alps, of which there are two principal distinct chains separated by the upper Rhone. The southern and loftier, or the Sardinian Alps, in which are Mont Blanc (15,744 feet), Monte Rosa (15,174), and the Matterhorn or Mont Cervin (14,836), and the northern or Bernese chain, the highest points of which are the Finsteraarhorn (14,026), and the Jungfrau (13,716). These unite in a central knot at St. Gothard, from which, spreading eastward, extends a wilderness of lofty peaks and ridges through the Grisons and Tyrol to the Glockner on the eastern extremity of that province, from which point, as from another centre or ganglion, branches ramify in various directions, the chain of the Rauch Alps extending north-eastward towards Vienna, and other chains proceeding east and south-east, and accompanying the coast line of the Adriatic, under the names of the Julian, Carnic, and Dinaric Alps, a range

whose mean altitude may be reckoned at above 5000 feet, and which rises in Mount Kom to 9000, from which part off innumerable ramifications, covering the whole region south of the Danube to the utmost confines of Europe.

(169.) The system of the Eastern Alps (the Slavo-Hellenic system), however, mainly diverges from the Sharah Tagh (10,000 feet)* in two directions. The Pindus chain running southward, traverses Macedonia, Albania, Thessaly, and Greece, down to the extremity of the Morea, and comprises in its course the most celebrated summits in classic lore, Olympus in Thessaly (9749 feet), and Parnassus (8068). The other, or Balkan chain, runs eastward along the forty-third parallel of latitude to the Black Sea, which it encounters near the Gulf of Bourgas and the promontory of Emineh Burun, consisting in its highest range, of the rugged and almost impassable chain of the ancient Hæmus (8874), parallel to which, lying directly east and west in the latitude of Constantinople, is the ancient Rhodope (8313). The whole is rugged in the extremest degree, and the broken outline of Greece, full of deep bays and harbours, and admirably adapted for a maritime centre, as well as the multitude of islands in the Archipelago, with the sheltered coasts of Thessaly on one side, and of Asia Minor on the other, testify to

* Perhaps this is an over estimate. It may be doubted whether any summit of the ancient Scardus or of the Hæmus range, or indeed any mountains of Turkey in Europe, except Olympus and the Kom and its adjoining group, exceed 8000 feet.

the continuation of the mountain system in the same general direction beneath the sea-level.

(170.) The great southern chain of the Pennine Alps descends with precipitous rapidity on the plains of Piedmont and Lombardy, around which the Cottian range prolonged into the chain of Maritime Alps, skirting the Gulf of Lyons, makes a vast circular sweep, and, crossing over Italy nearly to its eastern coast, embraces in its circuit the basin of the Po, and runs down the whole length of the peninsula, as the chain of the Apennines, attaining (it is said) at one point, Monte Corno, near Aquila, an altitude of 10,114 feet. Nor does it terminate with the Italian peninsula, but may be considered as prolonged into Sicily, running across the north of the island from east to west, and having for outliers the active volcanoes of Vesuvius, the Lipari Isles, and Etna. The ridge of the Apennines is of secondary limestone, and flanked on both sides, and largely interspersed, with tertiary strata, and along the west coast of Italy with volcanic rocks, both recent and ancient.

(171.) Of the Alps Proper, one of the most striking characters in contrast with other great chains, is the absence of elevated plateaus. Where the principal chains meet, instead of enclosing, as in similar circumstances in America and Central Asia, lofty districts, like Bolivia, Utah, and Thibet, we find quite the reverse—deep open valleys, giving to the whole system a decided

out-branching character. In their eastern ramifications this feature is modified, and among the Balkan group we find elevated districts of considerable extent, from which the higher summits rise as from a vantage ground.

(172.) The base of the higher Alps is calculated by Humboldt to cover an area of 24,300 square geographical miles. The principal chain, that of the Sardinian Alps, consists almost entirely of gneiss, mica slate, serpentine, with here and there granite, and other rocks more or less allied to true granite; that of the Bernese Alps is for the most part of secondary limestones, oolites, etc., much disturbed and altered by heat. North of the higher ranges occurs a broad zone of tertiary formation, and towards France the Jura limestone is so developed as to have received its name from the mountains in which it occurs. The Alps are considered by geologists to have gained an accession of nearly 4000 feet in height since the tertiary period.

(173.) The great plains of the north-east of Europe are separated in a very decided manner from the northern slope of the Alpine region, by the chains of the Hercynian and Carpathian Mountains, which form an oval basin (that of the upper Danube and the Theiss), including Bavaria, Austria Proper, Hungary, and Transylvania, and which connect themselves with the Balkan range by the North Balkan, a narrow passage only being left open at Orsova for the Danube. Some of the Carpathian Moun

tains are of considerable elevation, as the Eisthaler Thurm in the Tatra group (8632), the Lomnitz Point of the same group (8420), in the northern, and Pojano Ruska (9912) in the southern part of their chain. The Transylvanian system is remarkable for its mineral riches.

(174.) The great northern plain of the eastern continent is unbroken almost to the extremity of Siberia by any elevation worth mentioning, except the Ural chain, which marks the division of Europe and Asia, and which runs down in an exact meridional direction from the 70th to the 48th degree of north latitude, forming a rectilinear and nearly unbroken chain of 1300 geographical miles in length. Indeed, it may be considered as extending nearly 400 miles farther, to the extremity of Nova Zembla, making a considerable bend in its course at the arctic circle. It consists, along its western declivity, of the older palæozoic rocks, upraised by a line of metamorphic formation, along the whole length of which occur at intervals a series of newer igneous rocks, which would appear to have broken through at the time of upheaval, while yet forming a coast line, or chain of islands; at the southern end, for a considerable distance, granitic or other analogous rocks appear. Scarcely any mountain region is more rich in mineral productions, gold and platinum being richly produced in its central portions, and even diamonds in its southern. No part of this chain is very elevated. The Konstanti-

now Kamen (lat. 68° 30′) being 5000 feet, the Koniakofski Kamen (lat. 60°), 5397, and the Iremel (lat. 54° 20′) 5075 feet, nor does it exhibit any of those rugged and precipitous features which attend mountain chains in general. It would seem as if the upheaving force, whose general feebleness is manifested over the whole of this vast region, had barely been able along this line to overcome the superposed weight, and break out to day, but not to shatter rocks or throw up cones.

(175.) The transition from the great European mountain masses to those of Asia, is through the elevated plateaus of Asia Minor and Armenia, and the mountain chains of the Caucasus and Elbrouz, beyond which, to the north, the level sinks at once to that of the lowlands of the great northern area. Asia Minor presents several considerable mountain chains, the principal of which are that of the Taurus, which runs along the southern coast, and rises, in Mount Argeus in Karamania, to 13,197 feet, and the Anti-Taurus, bordering the Euxine, which [illegible] point (Argischtagh) attains 13,000. Asia Minor, moreover, offers the first striking instance in our progress eastward, of the general tendency to rise in elevated plateaux and table-lands, which distinguishes the medial zone of the great eastern continent. The mean elevation of the surface of the whole peninsula is not less than 3250 feet, with a central depression which, though not sufficient to form a basin (the country being intersected with many

valleys affording an outlet), allows the collection of numerous lakes, many of which are salt, one of them at Tutzla of considerable size.

(176.) The plateau of Armenia is still more elevated (7000 feet). It occupies a belt extending across the neck of Asia Minor between the Caspian, the Caucasian range, the Euxine, and the Mediterranean. It has several very lofty eminences, among others, Ararat, an extinct volcano, 17,212 feet in height, the summit of which is always covered with snow. The Caucasian chain itself runs along the north-eastern coast of the Euxine and the southern shores of the Caspian. Its highest points are Mount Elbrouz, a volcano still shewing some faint signs of activity, 18,493 feet, and Mount Kasbeck, 16,523, and the still, though torpidly, active volcano of Demawend, 14,695, not far from Teheran, the capital of the Persian empire.

(177.) We are now fairly entered upon that great succession of table-lands and elevated plateaus, which give a peculiar character to the eastern continent, and which, according to the opinions of the best geologists existed as such anteriorly to the protrusion of the great mountain chains which run across them. The general direction of this series of elevated districts (which comprehends the whole of Arabia, Armenia, Persia, Afghanistan, Thibet, and Upper Tartary, as far as, and beyond the desert of Gobi into Mongolia), is from W.S.W. to

E.N.E., while the general direction of the loftier mountain ranges, commencing with the Pyrenees and ending with the Himalayas, is from W.N.W. to E.S.E., forming an angle of from 45° to 50° with the former—a very significant fact as regards the geological history of the continent, and one to which, it appears to us, sufficient attention has not been paid.

(178.) Arabia consists generally of very elevated land. Along the eastern and central parts, an elevation of 7000 or 8000 feet has been assigned to it; but this is perhaps exaggerated, no country being so difficult of access, and offering such obstacles to exact determination. Its general character is that of excessive aridity, and all but complete absence of rivers, and, in the interior, of any running water whatever. Towards the southern coast it becomes somewhat lower, and a little less inhospitable. The Louskebir and Seger mountains, which skirt the south coast, range from 3000 to 5000 feet in height, and are rather to be regarded as the termination of the interior plateau than as chains *per se.* At the south-east corner, in Yemen, they retreat a little and leave some room for cultivation, and for the course of one of the only two streams which can be called a river in the whole of this vast country, whose general area is not less than 720,000 square geographical miles. The east coast, from Aden to Medina, along the Red Sea, is skirted, at a distance of 100 or 150 miles, by an almost continu-

ous range of mountains, which extend as far as Medina, from whence to the Gulf Akabah the coast-line is low, and admits of the passage of the caravans to Medinah and Mecca; but the mountainous character recommences at this point with Mount Sinai (7498), Horeb (8593), and Um Shomah (9300), granitic and slaty masses, intersected with basaltic dykes, and plunging down like huge towers and buttressed fortresses on the narrow plains or "wadies," which form the only habitable portion of the country. Arabia is crossed from the Red Sea to the Persian Gulf (from Mecca to Lahsa, celebrated for the pearl fisheries of Bahrein) by a mountain axis, along which lies one of the few lines of route by which the desert can be crossed, and from which a small river (the only other Arabia can boast) descends to the Gulf of Lahsa. The plateau of Arabia may be regarded as continued across the Red Sea (which runs up it as a deep but narrow rectilinear cleft about 150 miles in breadth, and 1300 in length, from Aden to Suez), into Africa, to form the lofty table-land of Abyssinia and Upper Ethiopia, where M. d'Abbadie has ascertained the existence of mountains 14,000 to 16,000 feet in height.

(179.) The plateau of Iran, which comprises about 350,000 square geographical miles, is also very elevated, though less so than Arabia. Its mean height may be stated at about 3000 feet, and, like Arabia, its interior is almost entirely destitute of rivers, and parched and deso-

late to an extreme degree. The line of the Zagros mountains, which forms the watersched of the Euphrates on its east bank, continues along the Persian Gulf into Beluchistan, and nearly to the Indus. It consists of a series of bordering ridges running parallel to, and separating the narrow sea-bord of that gulf from an immense inland or closed basin, to be more particularly described hereafter, and of whose entire extent the whole of this region forms but a very small fraction. On its northern limit, the Persian plateau runs up to the range of mountains bordering the South Caspian, which may be considered as prolonging the Caucasian range through Mazanderan and Khorasan to the lofty chain of the Hindu Kho, or Koosh; being, however, rather a mural limit to the extension of the table-land in that direction, than an independent mountain chain. Its junction with the much more lofty and continuous chain of the Hindu Kho is at Herat, which stands as it were in the Gate of India, from whence to Kuttore, at the eastern corner of Little Thibet, the incipient chain of the Kuen Lun on the north (of which the mountains in question may be considered a prolongation), and the terminal outlying eminences of the Hindu Kho on the south, run parallel for nearly 500 miles. The entrance to India from Herat, however, lies to the south of both these ranges, through Upper Afghanistan by the pass of Cabul, immediately adjacent to the lofty peak (20,232 feet) of the Hindu

Kho, the mountain which gives its name to the whole chain, and between this and the Sufieh Koh, the road lies along the Khyber Pass (of disastrous memory) to Peshawur, on the Upper Indus.

(180.) At Kuttore, about lat. 36° 40′ N., long. 72° 40′ E., the chain of the Kuen Lun, considered as prolonged westward in that of the Hindu Kho, and the Himalaya range, considered as prolonged in the arc of a vast circle north-westward into the Bolor Mountains, cross each other: and from hence up to the Lakes Rewan, or R'akas and Manasarowar, at the eastern extremity of Thibet Proper, in which the Sutlej and the Ganges have their highest recognized sources, these two great chains interlace and ramify in a vast ganglion of mountain masses of the first magnitude. In the eastern corner of this knot we find the elevated valley of Cashmir, an almost closed basin of an oval form, surrounded on all sides by the loftiest mountains, and 5800 feet above the sea, and in the interval the chain of the Himalaya rises to the altitude of 25,669 feet in the peak of Jumnotri, and 25,749 in that of Nanda-devi, the mean altitude being from 18,000 to 20,000 feet. These peaks, as is the case with most of the loftiest summits of the Himalaya, stand out at some distance southward from the main ridge, with which they are connected by long spurs. Pursuing thence the line of this chain along the province of Nepaul, where it skirts the districts of Kemaon, Sikkim,

and Bhotan up to Assam (a total length from Kuttore of not less than 1300 geographical miles), it comprises within its range a most astonishing series of lofty and snow-clad pinnacles. At least 40 peaks exceeding Chimborazo in altitude are enumerated in its course; among which we may name Dwalagiri (27,600 feet), long supposed the highest mountain in the world, which stands out from the general chain where the valley of the Gunduc River intersects it about the 83d meridian, but whose supremacy has been supplanted by two other summits at least, viz., Kinchinjunga (88° 30′ E.), which overhangs the Lacheh pass into Thibet (28,178 feet), and Gahurishanka, Chingopamari, or Deodunga (at present considered as the culminating summit of the world) in long. 86° E. (29,002 feet).

(181.) The Himalaya and Kuen Lun ranges afford a parallel on a much vaster scale to the phenomenon exhibited by the great mountain ranges both of North and South America. From their point of intersection at Kuttore to the 93d meridian, they open out into an oval expanse, about 500 or 550 geographical miles across, which is occupied by the plateau of Thibet, the loftiest inhabited region in the world, having, in its western or lowest portion—that occupied by the district of Ladak—an average elevation of 12,000 feet, and in its eastern, or highest portion, 17,000. Fifteen thousand feet may be taken as the average height of this wonderful plateau.

which serves as a base for a mountain system of its own, and which extends over 166,000 square geographical miles. On either side of it the mountains sink rapidly —to the north into the inferior but still elevated plateau of Upper Tartary; and to the south, by three gradations of inferior mountain ranges, running parallel to, and serving as terraced bases to the great central masses. The first descent is exceedingly abrupt, so much so, that in Bhotan, the change of level is upwards of 10,000 feet in ten miles, being, in fact, in many places almost a mural precipice. The substratum of the Thibetian plateau consists of secondary formations, but much of the surface is composed of quite modern detritus, in which are found the fossil remains of elephants, rhinoceroses, and other animals of the latest tertiary epoch. In the pass of Niti, too, by which the sacred lakes of Manasarowar and Rewan are approached, the occurrence of tertiary beds, already noticed in art. 120, proves the astonishing fact that this enormous plateau has actually been raised from the sea-level to its present elevation subsequently to the deposition of the newest of the great geological groups of strata. That it has been thrust up bodily through the general mass of the continent is equally clear—the detritus lying in horizontal beds, and the remnant of the formation thus marvellously preserved existing here alone, where the lofty ridges surrounding it on all sides, and

the extreme dryness of its new climate (a consequence of its great elevation), have preserved it intact from the causes of denudation that have acted on all the surrounding masses, and swept away from the south side of the Himalaya all but the older strata. With this exception, and with that of a considerable mass of volcanic formation in the neighbourhood of the sacred lakes, the highest portions of the Himalayas consist of granite, gneiss, and metamorphic rocks, and their southern flanks of fossiliferous limestones, and other members of the older and newer Palæozoic series—among which the Siwalik Hills are remarkable as having furnished specimens of that extraordinary fossil, the Sivatherium, or four-horned camel, discovered by Captain Cautley.

(182.) The chain of the Himalayas terminates rather abruptly about the 94th meridian east, where it is cut through by the Brahmaputra River and its tributaries, unless we prefer to consider it as continued somewhat further eastward by the parallel chains of the Assam and Khasya mountains, on the opposite side of the valley of the last-named river, at about 120 miles to the south; after which a system of mountain-lines following nearly a meridional direction, stretches into Arracan and the Malayan and Cambodian peninsulas, directing their rivers in nearly parallel courses southwards. The chain itself, for the last 330 geographical miles of its extent (from Darjiling eastward), follows very nearly

indeed the 28th parallel of latitude. It is by no means correct, however, to consider, as is usually done, the whole chain as, "generally speaking, parallel to the equator:" its whole previous course of 960 miles from the knot of Bolor, making an angle of 30° with that direction, from N.W. to S.E.

(183.) The line of the Assam and Khasya mountains, if prolonged across the valley of the Ganges, would find its continuation in the Rhamghur, Khymore, and Vindhya mountains, a range which separates Hindostan proper from the plateau of Malwa and Upper India; and it deserves remark that, so prolonged, the line runs a precise parallel to the Thian-shan, and nearly so to the eastern line of the Himalaya and the Tengri-nor range in Thibet. These mountains form the northern watershed of the valley of the Nerbudda, as the Satpore range does of the southern, up to the Gulf of Cambay. The peninsula of Hindostan itself is a great triangular table-land, or congeries of such, with intermediate low levels, bounded or sustained by these mountain ranges on the northern side, and by the Eastern and Western Ghauts on the others. Of these, the western forms an almost continuous wall, upwards of 600 miles long, rising, towards its southern extremity, to an elevation of 4700 feet. They support, as by a series of steep and mural buttresses, the plateaus of the Deccan, 1500 or 2000 feet high, and the still loftier table-land of Mysore (4000 to

5000 feet), the granite nucleus of which has been deluged with an enormous flood of basaltic lava. In this district are situate the diamond mines of Golconda, where this precious mineral is found in ironstone, and disintegrated clayey and marly strata. Towards the southern termination of the peninsula, the mountains become loftier. The Nilgheri hills (enjoying the most uniform and perfect climate on earth) rise to 8760 feet above the sea, and form a group in which, in a space of 40 miles long by 15 broad, 17 peaks, between 5800 and 8800 feet high, are enumerated. The Eastern Ghauts are lower and less continuous, and the general level of the peninsula slopes downwards towards the eastern coast.

(184.) The Kuen-Lun system of mountains is but imperfectly known, being very difficult of access from either side. It would appear to be prolonged far into China by the Pe-ling and Tapa-ling ranges; and, so prolonged, would present the imposing fact of a mountain-range extending over 64° of longitude from the Caspian nearly to the Pacific (3350 geographical miles), and nowhere deviating more than 2° in latitude from the parallel of 35½°. But in addition to this, it sends out a great branch to the N.E., which, under the names of Yn Shan and Kingan Oulah, prolongs the system into and over Mantchouria, up to the Sea of Japan and the mouth of the Amur.

(185.) The Asiatic chain next in extent and importance, is that of the Tengri or Thian Shan (Celestial Mountains), between which and the Kuen-Lun chain intervene the immense, high, and desolate plateau of Upper Tartary, and the sandy and rainless deserts of Gobi and Shamo, divided from each other by a deep depression, occupying together 380,000 geographical square miles in area, at a mean elevation, the former of 3000, the latter of 4300 feet of altitude. This chain is in many respects extremely remarkable; and although less elevated, is quite as leading a feature in a geological and geographical point of view as the Himalayas. In direction it is almost exactly rectilinear, and 1150 geographical miles in length, from the 72d east meridian, where it intersects the Bolor range, running north and south, to the 97th, and between the parallels of 41° and 43° N. lat. It may be considered, indeed, as continued west of the Bolor by the lower chains of Asferagh and Ak-tagh to the 66th meridian. And this can hardly be considered as a mere ideal extension, when taken in connection with geological relations, for it points directly towards the southern extremity of the Caspian, and but for the intervening flat and desert region of Kharesm, might be looked upon as a branch of the volcanic chain of Elbrouz. And, in fact, the most marking feature it offers is the frequency in it of volcanic vents, mostly extinct, but two of which, Pe-shan and Ho-tscheou (art. 127),

may perhaps be still occasionally active. These mark it out to have been one of the ancient coast-lines of elevation (an indication, on the great scale, quite as convincing as the traces of ancient sea-beaches on a small one) of a former tropical continent, to which the great plains of North Asia and North Europe form the same kind of appendage as the flat eastern portions of America do to the western coast-chain—a formation, that is to say, out of the detritus of the elevated region washed outwards into what was then a great and shallow northern ocean, and which, up to the present era, is in continual process of extension—along the coasts of Arctic Asia by the action of river deposit, and along those of north-western Europe by the more active agency of upheaving forces, the effects of which are traceable, from century to century, by the bodily uprise of the coast-line of Scandinavia, and which, in the lapse of some twenty or thirty thousand years (a period, geologically speaking, trifling), will, if continued, obliterate the Baltic.

(186.) The Altaï mountain system covers an area of about 35° of longitude and 8° of latitude, between the 46th and 54th parallels. They separate the Dzungarian and Mongolian plateaus (of no great elevation) from the low country of North-East Siberia. They consist of a series of ranges (the Alu-Tagh, Tangnou, Kiangshan, and Tschokindo mountains, which last, with the moun-

tain knot of Kentei Khan, attain an elevation of 7000 or 8000 feet), and inclose the Lake Baikal, and the sources of the Great Russian rivers, the Lena, the Yenesei, and the Obi. In the Tangnou are many eminences which rise above the limit of perpetual snow, and some near the head of the Oubsa river, above 11,000 feet. These mountains are extremely rich in mineral productions; and, to judge from the beautifully-executed drawings of Mr. Atkinson (*Western and Oriental Siberia*), it would seem scarcely possible for any region to surpass the whole of this mountain district in picturesque beauty. Around the Baikal Lake granitic masses abound, interspersed with newer igneous formations, and Mr. Atkinson reports an extinct crater near the Lake Karanur in the Tangnou, with a cone of ashes 800 feet in height (lat. 53° N., long. 97° E.) From the Baikal the mountain system is continued northward and eastward, through the Daurian mountains, in a series of branches under various names, as the Yablonoi, Udskoi, Aldan, and Stanovoi mountain ranges (or Krebets), up to the furthest extremity of the Sea of Ochotsk, and terminating in the volcanic system of Kamschatka, where there are several active vents, an eruption of one of which (that of Klieutschewsk, lat. 56° 33′, long. 160° 20′, 15,955 feet in height), in September 1829, Erman was fortunate enough to witness. (*Reise um die Erde*, iii. chap. 19.)

(187.) *African Mountains.*—Of the mountain systems of Africa our knowledge is very imperfect. The Atlas system and that of Abyssinia have already been noticed. The southern termination of the continent is formed of tabular sandstone masses, from 3806 feet (height of the Table Mountain) to 6000 or 7000, reposing on slate and granite, dykes of which latter run up into the superposed rock. The granitic formation, which in many places is thus capped with sandstone, is very extensively developed in South Africa. In the Kamies Berg it rises to 5100 feet in height, and the whole plateau of the Bushman flat, with a general elevation of from 2000 to 3600 feet, is granitic. The sandstone (which incloses rolled pebbles of pure quartz) is disposed in perfectly horizontal strata, proving the elevation of the land to have been performed with little of paroxysmal disturbance. From the rounded forms of the lower eminences, and the wide, sloping taluses, contrasted with the mural cliffs above in the loftier ones, commencing at a definite level, uniform over large tracts of country, we may consider this elevation to have been performed in two steps, with a long interval of tidal washing in a shallow sea between them. The Quotlamba or Snowy Mountains, a range rising to the altitude of 10,000 feet, run along the east coast northwards toward the Zambesi river, explored by Dr. Livingstone, being prolonged in that direction under the names of the Fura Mountains.

while the chains of the Beth and Lupata, 8000 or 10,000 feet in altitude, follow the coast of Zanzibar, and a loftier and more central chain (the Sierra Maxengo) runs north from the 16th parallel of south latitude, supposed to rise to 17,000 feet in its highest part. This divides into two branches, which enclose between them (as it is supposed, from the reports of natives to M. Ehrardt, rather than any actual exploration) a great interior lake, Nyassi or Uniamesi, equal to the Caspian in size, of fresh water, beyond which they reunite and form a system of equatorial mountains covered with perpetual snow, two of which, Kilimanjaro (lat. 3° 20′ S., long. 37° 15′ E.) and Kenia or Kignea, very nearly on the equator, in long. 38° E., have been visited by M. Rebmann and Dr. Krapff. A large part of South Africa, however, appears, from the account of Dr. Livingstone, to be occupied by a considerably elevated table-land, and towards this region the mountains of the coasts would seem to dip inwards both ways. From the equator, in the direction of Abyssinia, would seem to extend lofty table-lands of 7000 or 8000 feet in elevation. Along the west coast, from the Cape of Good Hope northwards to Cape Negro, occur no lofty mountain ranges. Inland, behind Benguela, Congo, and Loango, the land rises in a terrace, backed by the Sierra Cumpleda, a range 12,000 or 15,000 feet in height, and at the Bight of Biafra the Cameroon mountain

attains 13,000, to the north of which the Kong mountains, and the coast range of Sierra Leone, are probably to be considered an extension of the equatorial mountain system, dying out northward towards the Great Sahara Desert.

(188.) *Australian Mountains.*—Of this great continental mass, so little of the interior has been explored, that we hardly know anything of its general mountain system. So far as we do know, the highest land lies along the east coast, forming a range from Torres Strait, continued out southward to Van Diemen's Land, nowhere receding more than 150 miles from the sea. Though not lofty (Mount Koschiusko, the highest point, does not exceed 6500 feet), the material of which it consists (which is chiefly granite and porphyritic mixed with volcanic rock), gives them a singularly rugged and inaccessible character, especially coastwise, while towards the interior the slope is gradual. The heights of several points in this range, determined by Count Strzelecki, will be found in the Appendix.

(189.) Of Rivers.—All rivers owe their origin, of course, to atmospheric precipitation, and their magnitudes are in a compound proportion of the area of their basins of drainage, and the average annual amount of precipitation. But the greater or less deviation from uniformity in the volume of water delivered in different seasons, which is a feature of the greatest importance in

the physical character of a river, depends much on the mode in which the water reaches its channels, which may be in either of three ways. 1. From immediate surface-drainage, *i.e.*, from rain actually falling, and drained off without penetrating the soil. 2. From springs, *i.e.*, rain-water which has penetrated the ground by infiltration, and collected in subterranean channels, which at length open out at the surface, or in some cases in the beds of lakes and rivers; and 3. From the melting of snow on the summits of mountains during the summer. Intermediate between the supply from springs and from surface drainage, must be classed that portion of the rain which oozes out at low levels from a saturated soil, in innumerable rills, not distinctly traceable to any perennial spring delivering a visible volume of water. The soil, when porous, acts as a reservoir, and its gradual drainage tends to equalize the monthly delivery of rivers, and feed them in the dry season. In climates, then, where there is no broad division of the year into a rainy and a dry season, where the soil is porous and habitually moist, and where the highest levels of the watersched are below the line of perpetual snow, or where such snow-fields are not largely developed, the rivers are subject to no periodical irregularities, but only to those which result from unusual, long-continued rains and droughts. Such are most rivers in the temperate zones. Where floods occur in such rivers, they

depend quite as much on the nature of the soil drained as on the weather. The floods of the Rhone, occasionally so very destructive, arise mainly from the sudden delivery of heavy rains on the rocky soil and steep valleys of the Côte d'Or and Jura mountains, which form the basin of the Saone. Those which, in 1829, desolated Morayshire, in Scotland, originated in no sudden and violent rains, but in a long-continued drizzling and misty state of the atmosphere, bringing great tracts of heathery and mossy ground to the state of a saturated sponge—a state of things which sometimes results in the breaking loose of peat mosses, as that of the Solway Moss in 1772.

(190.) On the other hand, when the rains are periodical, and the year divided into a dry and a wet season, which is the case with intertropical regions generally (METEOROLOGY, art. 112), the rivers rise and fall periodically also; the commencement of the rise in the lower part of the river-course being posterior to that of the upland rains, owing to the time required for the water to descend, and the more so the longer the course of the stream. Thus, the inundation of the Nile, which may be taken as a normal case of river periodicity, and whose continuance for successive ages as the source of all the prosperity of the most anciently civilized region in the world, has been an unvarying theme of wonder and eulogy, begins to be felt in Abyssinia and Sennaar in

April, while the rise is not perceptible at Cairo till near the summer solstice. In the last 1200 miles of its course, the Nile receives no affluents, and the increasing evaporation consequent on the progressive rise of annual temperature no doubt has some share in producing the retardation.

(191.) When the waterched line of a river basin is sufficiently lofty to receive and retain abundant snow, this acts as a reservoir, and detains the precipitated moisture during all the cold season. As the summer advances, the snow melts; and if the limit of *perpetual* snow be attained, the supply so husbanded continues during all the warm season. This may or may not be strictly coincident with that from the periodical rains; though since, generally speaking, in intertropical regions these are at their maximum when the sun is most nearly vertical, the two causes for the most part conspire. Thus, the floods of the Indus depend chiefly on the melting of the snows of the Himalaya from April to September (but little rain falling on its lower basin), and are at their maximum in July. Those of the Ganges and Brahmaputra afford an example of a want of exact coincidence in this respect, all the lower country adjacent to them being flooded by very heavy rains before the water from the melting of the snows (which in the Brahmaputra has a wide circuit to make before reaching the plains) has time to arrive.

(192.) When the level of perpetual snow in the watersched is not attained, its complete fusion sets a limit to that supply; and where little rain falls in summer, we have mountain torrents which cease, or afford but a scanty supply during the hottest months, as is the case with many streams in Greece, Italy, and especially Spain; with the Orange River in South Africa; etc.

(193.) Extensive lakes in the upper part of a river's course greatly tend to equalize its flow by acting as reservoirs. Thus the St. Lawrence, which, with a drainage basin of 297,600 square geographical miles, has 94,000 of them occupied by lakes, maintains an almost perfectly equable flow in all seasons. On the contrary, where no lakes exist, owing to a want of surface inequality, and especially where the declivity of the ground over large regions is very slight, inundations take place on every considerable increase of the volume of water to be disposed of, owing to the want of proper channels to carry it off. Thus the Silvas, or flat wooded plains of the basin of the Amazons River (an area of more than half a million of square miles), are for the most part so level and so little inclined, that the tract of country, 1740 geographical miles in breadth, from the eastern declivity of the Andes to Grand Para, has only a slope of 25′, and under the parallel of 5° from Cape St. Roque westward to Jaen de Bracamoros, 2640

geographical miles, across the greatest breadth of South America, a fall of 16″ only, or 1 foot in 13,000 (Humboldt, *Asie Cent.* i. 90). In consequence, in March, when the river is fullest, a very large proportion of this vast area is one great standing pool, all the small drainage channels having become obliterated in the dry season.

(194.) But besides the detention of snow on the watersched lines of a river basin, the general elevation of those lines, and of the district they inclose, is very influential in determining the annual average of precipitation itself, that is to say, the degree in which the rain-bearing winds, in passing over the river basin, become drained of their moisture. Such precipitation (METEOROLOGY, art. 110) is mainly determined by the vapour-laden air rising to a higher level in its progress, dilating, and losing temperature by so doing, a process which takes place of necessity whenever the atmosphere of any district is swept bodily *up the country* during the moist winds. The height of the watersched then, and its situation as regards the prevailing moist winds, are points of primary importance in determining the volume of water discharged by a river. This consideration, we may observe, is alone sufficient to render an account of the great meteorological fact (if such it really be), that the northern hemisphere receives more rain than the southern, without having recourse to the hypothesis of

the trade-winds crossing at the equator, of which it has been adduced as a proof.—(Maury, *Phys. Geog. of the Sea*, § 174.)

(195.) *Courses and Slopes of Rivers.*—The courses of rivers are of necessity regulated entirely by the direction of the lines of lowest level (art. 137), and are determined therefore, by the same causes which have regulated the upheaval of mountain chains, and the dislocation of their strata. Hence it follows that the courses of rivers very frequently follow the escarpments of cliffs abutting on flat or gently-sloping country; such cliffs, when not ancient sea cliffs, being usually indications of lines of fracture in the act of upheaval, or the out-cropping edges of inclined strata dipping from the escarpment inward; and thus it often happens that sudden turns in a river course correspond to changes in the geological features of the country. When a river, too, which has run for some distance between parallel mountain chains, escapes by a cross valley laterally, such valley is very commonly identifiable, by the inclination of the strata on either side of it, as a valley of cross fracture, accompanied with its own peculiar dislocations. And in some cases earthquakes have been known to open channels by which the courses of rivers have been diverted. The falls of the Zambesi, as described by Dr. Livingstone (see art. 232), can hardly have originated in any other way.

(196.) The velocity of the water in a river is greatest in mid-stream, at some little distance below the surface; the bottom and sides being retarded by the friction of its bed and banks, and the intermediate water by friction on that which moves with less velocity than itself. The retardation is greater the more the river bed winds, the more it is obstructed by shoals or by irregularities in its bottom, especially where shallow; and thus it happens that in the case of an inundation, such as that of the Amazon, the slope there indicated, which, if uniform, and along a regularly-worn channel, would be quite sufficient to carry off the water across the country, fails to do so. The slopes of rivers are for the most part very gentle. Thus, Mr. Rennie found the fall of the Thames from Chertsey to Teddington Lock to be 17½ inches per mile, corresponding to a slope of 57″ (one inch per mile corresponds to 3.26″). The Nile, between Assouan and Cairo, has an average slope of 6½ inches per mile (21″). La Condamine assigns to the Amazons an average slope of 6⅓ inches per mile (20″.65). The Ganges, according to Rennie, slopes 4 inches, or 13″.04. The Rhone is the most rapid river in Europe (perhaps, for so long a course, in the world). From the Lake of Geneva to Lyons its slope is 4′ 24″, from Lyons to its mouth, 1′ 46″. The average velocity of the Nile is about 2¾ miles per hour, of the Ganges from 3 to 5. The velocity of rivers, however, depends much more on their depth, and on the

body of water conveyed, than on their slope (except when much exceeding these limits), as the velocity generated by the mere fall of water is almost wholly destroyed at every instant by friction.

(197.) *Springs—Caves—Thermal and Gaseous Springs—Petroleum and Naphtha Wells—Gaseous Orifices.*—The welling forth of streams from perennial springs is of the most ordinary occurrence, but it is seldom more than a rivulet which rises in this manner. There are, however, some instances of considerable streams so originating. When this is the case, they issue from caverns, and these occur usually either in ice or in limestone. In the former case they are evidently only the drainage of melted snow, which pours out at the foot of a glacier by the contribution of subglacial streams converging to the lowest point. Such is the source of the Arve from the Glacier des Bois, at Chamouni, and such that of the Ganges, which emerges as a stream, already 40 yards in breadth, from a huge cavern in a perpendicular wall of ice near the temple of Gangutri (lat. 30° 59′ N., long. 78° 59′ E.) Limestone formations are very apt to be hollowed into caverns by the solvent power of carbonic, and perhaps also of other acids derived from vegetable decomposition, held in solution in the percolating water. Such caverns often run to great distances under ground, and frequently contain running streams, even considerable rivers, as is the case in the caverns of the Peak and Castleton in

Derbyshire, and in that of the Nicojack Cave in Georgia, U. S., on the Tennessee river, where a waterfall occurs, at a distance of three miles under ground (*Ed. Ph. Jour.*, i. 426). When such streams emerge to day, we have the phenomenon in question, as in the cavern of the Gaucheros, in the valley of Caripe, in Cumana, described by Humboldt; in the celebrated fountain of Vaucluse, which issues as a considerable stream from a cave at the foot of a perpendicular limestone cliff; and in a great number of caves in Carniola and Illyria, where "almost every lake or river has a subterraneous source, and often a subterraneous exit. The Laibach river rises twice from the limestone rock, and is twice again swallowed up by the earth before it makes its final appearance"—(Davy). The rivers Sarapa and Blanco, which flow from the lake of Yojoa in Honduras, both enter subterranean channels, through which having passed, in the one case a mile, in the other a mile and a half under ground, they reappear.

(198.) When water, carried down to a great depth into the earth, is forced up again by hydrostatic pressure through other channels, and rises as a spring, it brings up the temperature of the greatest depth to which it has penetrated, and that sometimes a very high one, even out of the neighbourhood of any volcanic formation. The warm springs at Bath have a temperature from 93° to 117° Fahr., those of Bareges and Bagneres 120° and

123°. In the county of Bath, in Virginia, a "warm spring" (96° Fahr.) issues in sufficient volume to turn a mill, and a "hot spring" (108°) rises at a few miles distance. Three springs at Yom Mack, near Macao, have temperatures of 132°, 150°, and 186° Fahr. respectively. On the Arkansas river are springs of 180° and 190°; at Broussa, in Asia Minor, the water rises scalding hot; at La Trinchera, near Valencia, 194°.5, in a stream 2 feet deep and 18 feet broad; at Jumnotri, in the Himalaya, nearly boiling; at Urijino, in Japan, fully boiling; and in the Geyser fountains at Reikiavik, in Iceland, it is spouted intermittently, in a torrent to the height of 150 ... 200 feet, actually boiling. In this case there can be no doubt of its having traversed a bed of lava not yet cold. A simple and perfect imitation of the phenomenon is produced by heating the stem of a tobacco-pipe red hot, and holding it horizontal, the bowl being filled with cold water. If we consider that the temperature of the earth increases at an average rate of about 1° Fahr. for every 90 feet of depth, these facts will not appear at all surprising. The permanence of their temperature is a proof of their obtaining it at great depths. At Mont Dor the very bath exists which was constructed in the time of Cæsar. At Yakutsk, where the soil is frozen to a depth of 630 feet, Mr. Atkinson informs us that hot springs exist, and afford in their neighbourhood opportunities of culture.

(199.) Many springs rise impregnated with carbonic acid,—those of Carlsbad to the amount of 12 cubic inches to the pint, and that of Bilin 34 inches. The warm spring of Wildbad in Wirtemberg, contains in a pint of water 12 cubic inches of carbonic acid, 7.9 of azote, and 8 of oxygen (Daubeny, *Report*, etc., B. A. 1836). Sulphuretted hydrogen also is no uncommon ingredient, as in the sources of Baden, Harrowgate, and St. Armand. Saline ingredients often enter to a large extent, and springs of brine occur in many localities, as at Droitwich in Worcestershire, at Halle in Saxony, and at Luneburg. Other salts of soda also occur in abundance; thus the springs of Carlsbad alone have been computed (from analysis) to give out annually more than 13,000,000 lbs of carbonate, and 20,000,000 lbs. of sulphate of that alkali (Gilbert). Borax is found in the lakes of Thibet, and free boracic acid in the Lagune of Tuscany. Lime and magnesia enter as muriate and sulphate. Silica occurs in the boiling springs of the Geysers.

(200.) Springs of petroleum and naphtha occur in Zante, in Modena and Parma, in Sicily, and many other localities. In the Burmese territory, on the Irawadi, there are upwards of 500 wells yielding annually 400,000 hogsheads of petroleum. In Trinidad there is a lake of mineral pitch three miles in circumference, partly liquid, partly solid, and fluid bitumen rises through the sea near

that island. Petroleum wells have recently been opened over a very extensive district in North America, near Cleveland, Ohio, and on the banks of Oil creek, a branch of the Alleghany River in Erie county, Pennsylvania—also at "Tidionte" in Warren county, where are seventeen wells stated to yield the almost incredible quantity of 10,000 gallons a day. The oil is pumped up with water from shallow wells, mere pits, and, floating on the surface, is collected. It is stated to burn well and *to be highly lubricating.*

(201.) Carburetted hydrogen gas is discharged from the earth in many regions where coal abounds. At Fredonia, in New York, U. S., it is conveyed in pipes for lighting and domestic use. In the province of Tsechuan, in China, it is also so used. At Thsee-lieou-tsing, a single source of gas heats 300 kettles. At Pietra Mala, near Florence, carburetted hydrogen rises through limestone, and may be set on fire. At Bacou, on the Caspian, flames (doubtless owing to gas on fire) are often observed to run over the hills. Something of the same kind is said to occur in the country between Namur and Liege.

(202.) Springs occasionally intermit and flow again in regularly recurring periods. That of Paderborn, in Westphalia, discharges water twice in the 24 hours—the discharge being accompanied with a loud rumbling noise. The cave of Kilcorney, county Clare, in Ireland, generally

dry, discharges a great flood of water quite suddenly two or three times in the year (*Phil. Trans.*, 1741). The lake of Zirknitz, near Trieste, is half the year a hay field, and the other half full of water discharged from a limestone cavern.

(203.) *Perpetual Snow.*—The summits of many mountains are covered with perpetual snow. The cause is found in the decrease of temperature in ascending from the sea-level (METEOROLOGY, art. 22). The rate of decrease being pretty nearly alike everywhere, the snow-line is sooner attained in high than in low latitudes. In EUROPE, in Iceland, and at the North Cape (lat. 71° 10′), the snow-level is about 2000 feet above the sea. In Norway, between 59° and 65° N., from 4000 to 5000. On the Alps (47°) and Pyrenees (43°), from 8000 to 9000. In the NEW WORLD, along the Andes, commencing with the Straits of Magellan, we find it in 54° S. so low as 3700 feet, with glaciers descending to the sea-level; but it rises rapidly on proceeding northward, attaining 8300 in 40° S., 12,780 in 33° S., and 13,800 in 27° S. Along the Chilian Cordillera, from 14½° to 18° S., the snow-level is 15,900 feet on the eastern, and 18,500 on the western side—the cause of the difference being the greater hygrometric dryness of the leeward side of the ridge; and in the great equatorial range of volc

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the chain in Mexico (19° N.), it is 14,760. In ASIA, the snow-levels present a contrast to these quite as striking as that between the mountain systems of the two continents, with whose general direction and manner of grouping they stand connected. Thus proceeding from high to low latitudes we find (Humboldt, *Asie Cent.* iii. 360).

	Lat. N.	Snow-level. Feet.
Aldan Mountains	60°55′	4476
Kamschatka	56 40	5233
Altai Mountains	50 —	7034
Caucasus	43 —	10,840
Ararat	39 42	14,170
Mount Argæus	38 33	10,705
Bolor Mountains	37 30	17,010
Hindu Kho	34 30	18,735
Himalaya, North side	31 —	20,930
——— South side		13,070

In AFRICA, we have nothing dependable except that in Morocco, Abyssinia, and on the equator, snowy mountains occur. But in the southern ocean, it deserves notice, that not only in such high latitudes as 75° S., that of Mounts Erebus and Terror, but in the much lower latitudes of South Shetland (62° 30′), the South Sandwich group (59°), and even South Georgia (54° 40′), the snow-line reaches the sea-level.

(204). The snows and glaciers of the Alps are reckoned to occupy 1400 square miles (Forbes, citing Ebel), upon which the melting effect of a hot summer

day, taken at three millions of cubic feet per square mile per diem,* would afford 4200 millions of cubic feet of water, or about 1-40th of a cubic mile per diem for the supply of the streams running from them.

(205). The snow-fields on the tops of mountains are prolonged downwards beyond their natural and proper level, by *glaciers*, which are accumulations of snow thrust down by pressure, *a tergo* into precipitous valleys, and pressed and hardened by alternate partial thawing and "regelation" into ice. Their phenomena are very curious; but having been made the subject of a lucid and elaborate special article in the work to which this essay was originally a contribution (See *Encyclopædia Britannica*, art. Glacier), by one who, from personal research, and long meditation, is probably better qualified than any one else to describe and explain them, we prefer referring the reader to that article for all that concerns their descent and progress. There is, however, one feature in their history which especially concerns our subject, viz., the abrading and transporting power of glaciers. Every glacier carries down with it blocks of stone, and smaller fragments, which it deposits, on melting in the valleys, in heaps and mounds of "moraine," distinguishable as such by the angular and little-worn character of the masses. Where such glaciers run out to the sea-coast in high latitudes,

* This supposes one-third of the sun's vertical power (at the sea level) to be effective for fusion during nine hours per diem.

and break off, they carry with them, as icebergs, these masses (often of very great size), which they deposit on melting at the bottom of the sea. Thus is explained satisfactorily a phenomenon which at one time gave rise to an infinity of wild speculation—the occurrence of "erratic blocks" and granite boulders, in localities very far from any mountain-masses of like material: on the limestone slopes of the Jura, for instance, with the whole valley of Geneva and its lake interposed between them and their obvious original site in the peaks of Mont Blanc, or on the sandy, alluvial plains of North Germany, with the Baltic intercepting their transport (otherwise than by this sort of water-carriage), from the Scandinavian mountains. Geologists seem agreed, that in such cases resort must be had either to a formerly existing glacier slope at an earlier geological epoch, or to their floating off on icebergs on the bosom of an ancient ocean, a process which we see going on under our eyes. Often, too, unequivocal signs of glacier action are exhibited in deeply-grooved and friction-worn surfaces of rocks *in situ*, the evident work of angular fragments forced along them with violent pressure; and in northern latitudes similar indications (as in the hills north of the St. Lawrence) testify to the heavy grinding of icebergs drifted along at an epoch when the whole of that region formed the bed of a shallow sea, extending probably to the pole. We come now to describe more

particularly the phenomena of rivers, commencing with those of the New World, as in the case of the mountains.

(206.) *Rivers of South America.*—All the more considerable South American streams flow eastward into the Atlantic, the narrow strip of western slope from the Andes to the Pacific being too confined, and the climate for the most part too dry, to nurture anything beyond small mountain-streams. In fact, from Valdivia northward, their whole supply from the snow, which lies in much less abundance on that side. Of the rivers that flow eastward, those of Patagonia, from the extremity of the continent to the mouth of the La Plata (lat. 35° S.), are of small magnitude, with few or no affluents, and making straight across the dry and shingly desert terraces of Patagonia for the sea, a region sterile and desolate in the extremest sense of the word. Beyond these, a total change of character in the river system, consequent on the changed character of the climate, commences, and we find vast rivers, with an immense development of affluents—the principal of which, in their order of occurrence, are, 1. The La Plata or Parana—for the former name appertains only to the wide estuary of Buenos Ayres. 2. The San Francisco, whose mouth is in 10° 40′ S. lat. 3. The Paranahyba (2° 45′ S.) 4. The Rio Para, or Tocantins (0° 40° S.) 5. The Maragnon, or Amazon, which may be considered as

falling into the sea exactly on the equator; and, 6. The Orinoco (8° 40′ N.)

(207.) The Rio de la Plata collects its waters from three very different descriptions of country. From the eastern slope of the Andes, between the 19th and 25th parallel of south latitude, it receives the Pilcomayo, the Vermejo, and the Salado, streams not much explored, which traverse salt deserts, and the wild and inhospitable region of the Gran Chaco. The Salado is brackish, and, as laid down by Commander Page in his track survey, exhibits perhaps the most tortuous sinuosities which can be found in river navigation. From the north it receives the Paraguay, with its numerous affluents, which drain the central plains between the 13th and 25th degrees of S. lat., and the western slopes of the Brazilian mountain system, the Sierras of Arapares, Calhano, and Amambahi. This is a magnificent river, navigable from Corrientes (lat. 27° 28′ S., where it joins the main river) nearly to its sources in lat. 13° S. It flows through a country of most luxuriant vegetation, but in all the lower part of its course, is subject to great and destructive inundations. The eastern branch, which carries the name of the Parana till it forks into the Rio Grande and Paranahyba (not the great river of that name) drains the interior of a large basin included by the coast sierras on the east, the sierras just mentioned on the west, and the Montes Pyreneos on the north,

a district including much of the richest part of the Brazilian territory. The Uruguay, which drains the basin included between the Sierra de Bitoanos and the Albardao de S. Ana, runs parallel to the Parana, and joins it at the estuary of La Plata, a shallow sea of fresh water, 180 geographical miles in depth inland from the coast, and 120 broad at its mouth. The total area drained by this magnificent river system is no less than 886,000 square miles. A fine survey of the course of the Paraguay has been recently executed (1855) by the government of the United States, under the direction of Commander Page above mentioned, in the steamer Waterwitch.

(208.) The basin of the San Francisco is contained between the coast sierras from Rio de Janeiro to Cape St. Roque, and the mountains parallel to them forming the next interior range of the Brazilian system, the Sierras Tiririca, Tabatinga, Gorgueha, and S. dos Irmaos. Its course between these ranges is generally from south to north, and their direction and continuance northward would lead, by a natural course, to an embouchure on the north-west coast, beyond the Cape. But about the 10th degree of S. lat. it turns suddenly to the eastward, and, cutting through three successive parallel sierras empties itself on the east coast, thus affording a striking illustration of the general fact noticed in art. 195, since the course actually pursued is precisely along the line

of demarcation which separates the granitic formations of this coast from the tertiary and alluvial ones of Pernambuco and Maranham. The basin of the San Francisco includes the district of Minas Geraes, the great source of the mineral wealth of Brazil. It includes an area of 187,200 square geographical miles, and the river itself is 1400 miles in length to its source in the Sierra da Matta da Corda. The Paranahyba River, which drains the province of Maranham (a basin of 115,200 square miles), offers little of interest beyond the facilities it affords for internal communication, which, as is the case with all the rivers of south America, are the most complete and perfect which the world possesses, the whole of that vast continent east of the Andes being accessible from the sea into almost every corner, granting only the aid of steam navigation.

(209.) The Rio da Para is the joint estuary of two great streams, the Araguay and the Tocantins, which drain the interior of the Brazilian mountain system, following a parallel course on either side of the meridional chain of the Cordillera Grande. It enters the sea so near the mouth of the Amazon (being separated from it, however, by the so-called island of Marajos, of about 9000 square miles, behind which the narrow channel of Tagipuru runs from river to river), that it is sometimes called an affluent of that river. The Amazon itself, by far the largest river in the world, since the

area of its basin exceeds 1,500,000 square geographical miles, is fed from the eastern slopes of the Andes, from the 2d degree of N. to the 19th degree of S. latitude. Its most remote feeder is the Apurimac, which descends from the extreme edge of the plateau of Bolivia, near Caillomas, 3000 miles from its mouth (following the stream), and among its affluents has many which would rank as first-rate rivers. It enters the ocean by an estuary 135 geographical miles broad and 200 long, but which wholly consists (at least superficially) of fresh water. It is navigable 2200 miles from its mouth, and by reason of the flatness of the greater part of the region it traverses, there is but little interval between its head waters and those of the Paraguay, on the one side, and none between it and the Orinoco on the other, inasmuch as one and the same tributary, the Cassequiare, belongs indifferently to both river systems, the level being so complete at one point between them as to obliterate the line of waterscheed, and establish a natural and permanent canal uniting the two basins (see art. 140). The principal affluent of the Amazon (considered as prolonged in its main stream under the names of the Solimaes, the Maragnon, and the Yucatale, to the Apurimac) is the Madeira, which rises among the farthest inland mountains of the Brazilian system, and whose course, from the extremity of the Cordillera Geral, where it leaves them, is by a great series of

cataracts and rapids down to the plains. The length of this river, from its junction in 57° 40′ W. to its extreme source in the Rio Grande, which rises among the mountains north of Potosi, is not less than 1600 geographical miles; the vast and almost unexplored region between the two rivers, and, indeed, nearly the whole course of the Maragnon itself, from the junction upward (an area of more than half a million square miles), being occupied by dense and all but impenetrable forests (the Silvas of the Amazon), deluged by the equatorial rains, whose effects in flooding the country during the northward progress of the sun have been already described (art. 193). Besides the Madeira, the Amazon receives as tributaries the important rivers of the Negro, the Tapajos, and the Xingu, the former extending towards the sources of the Orinoco, and forming a junction with it by the Cassequiare, as already mentioned, the two latter draining the interior basin between the watersheds of the Araguay, the Paraguay, and the Madeira.

(210.) The basin of the Orinoco includes the western slopes of the mountain system of Parimé, and the eastern of the Cordilleras of New Granada. North of the equator its supply of water, area for area, is even greater than that of the Amazon. For, in the interior of Guiana, 560 miles from the coast, when full, it exceeds three miles in breadth, and the rise of the waters at this part of its course, in the periodical floods,

is from 30 to 36 feet. These floods take place in that half of the year when the sun is north of the equator (the course of the river lying on that side of the line), and the quantity of rain which falls on the area must be enormous, probably not less than 200 or 300 inches annually. (Mrs. Somerville, indeed, states it at 1000 inches, we know not on what authority, but if this be correct, it can only be that the rain which falls during one period of the day, in the wet season, is in great part evaporated in the other, and, in fact, that the same water falls over and over again.) Where the Orinoco leaves the Parimé mountains at Atures, its course is broken by falls and rapids there and at Maypures, which, though not deep enough to merit the name of cataracts (being only 30 or 40 feet), have attained celebrity in the picturesque description of Humboldt (*Aspects*, i. 219), from the vast volume of water poured down, and the singularly rugged nature of the ground. At these falls, too, there are manifest indications of the course of the river having at some former period been elevated from 160 to 190 feet above its present level.

(211.) *Rivers of North America.*—In North, as in South America, all the great development of the hydraulic system is on the east side of the Pacific mountain chain, the *North American Andes*, as it may fittingly be designated. Towards the Pacific, however, owing to the broader extent of the mountain belt the

streams are not so stinted as in the South, and we find, too, the Colorado and the Columbia, which merit the epithet of great rivers, the former (which falls into the Gulf of California) having a basin of 170,000, the latter of 194,000, square miles,—streams which, however, derive greater importance than belongs to their mere magnitude, from their representing, with the Sacramento, the drainage of the great gold-fields of the West. The loftiest waterfall in the world (unless exaggerated), is to be found in the Yohamite Valley, in Mariposa (?) County, California, where a river as large as the Thames at Richmond makes a single leap of 2100 feet perpendicular, the total height of the fall being 3100 (Gibson). On the east side of the coast ranges we have six great river systems, two of them of the first magnitude, viz., the Rio Grande del Norte and the *Mississippi*, which fall into the Gulf of Mexico; the *St. Lawrence*, into the Atlantic; the Saskatchewan and Churchill, into Hudson's Bay, and the Mackenzie, into the Arctic Ocean.

(212.) The Rio del Norte derives its waters almost entirely from the mountain ranges which buttress the table-land of Mexico (the Cordillera of Cohahuela, and the Sierras Madre and de lo Mimbre), and receives little or no accession in traversing the intervening slopes to seaward. Its extreme feeders abut on the eastern borders of two considerable closed areas, or "continental basins," which collect, and suffice to evaporate, the

waters of the northern portion of the Mexican plateau, leaving, as usual, lakes more or less salt.

(213.) The magnitude and importance of the Mississippi will be at once appretiated from the fact of its draining nearly a million square miles of territory, admirably adapted for human habitation, and inhabited, in fact, by the most active and rapidly-increasing population in the world. Its line of watersched is very remarkable for the difference of altitude in different parts of its extent. On the west, from the 38th to the 48th degree of N. lat., it consists of the ridges of the Rocky Mountain range, averaging eight or ten thousand feet in altitude, while on the north, the division of the American waters which flow north from those which run to the south, cuts across the central plain of the continent, between the 46th and 50th parallels, and (except where it branches from the mountains), is nowhere more than 1500 or 1600 feet in elevation, to its intersection with the western watersched of the St. Lawrence basin. This entire river system consists of three great branches, the Missouri and the Mississippi (uniting at St. Louis, lat. 34° 84′, long. 90° 12′), and the Ohio, which falls in somewhat lower at New Madrid (36° 32′, 89° 32′), the Missouri receiving the waters from the western mountains, the Mississippi from the central slope, and the Ohio the inland drainage from the Appalachian mountain chain. Each of these is a

magnificent river, with a great system of affluents. The Missouri is navigable from the *Great Falls*, in the Rocky Mountains, to the sea, a distance of 4000 miles; the Mississippi, from those of St. Anthony, 2240; while the Ohio, being connected by a system of canals with Lake Erie, and thence with Lake Ontario (so as to evade the falls of Niagara), carries out a water communication between the Gulfs of Mexico and St. Lawrence. The average slope of the Mississippi, from its source, is 19·87 in. per mile, or 1 in 3189 (corresponding to a slope of 1′ 4″), or about three-fourths that of the Rhone. It is therefore no sluggish river, but in many parts of its course, a torrent, against which steamers with difficulty make head, and which rushes down laden with drift timber from the (yearly disappearing) forest, of the vast alluvial region it traverses, cutting down timber laden banks (whose section discloses the forest growth and destruction of hundreds of thousands of years—*Lyell*), and carrying all out to sea through a delta of unexampled extent (see art. 106). The Arkansas and Red River join the Mississippi below New Madrid. Their course is through the desert country on the east slope of the Chippawyan range, and they and their affluents cut through the terraces parallel to that range, almost at right angles.

(214.) The St. Lawrence drains a vast table-land, whose highest point is not more than 1680 feet above

the sea, and of which a very large portion is occupied by lakes, whose united waters constitute more than half the fresh water on the globe, and of whose extent, depth, and height of their surfaces above the sea, Mr. Johnston (*Phys. Atlas*, p. 157) has given the following synopsis:—

	Extent in Square Miles.	Elevation above Sea.	Mean Depth.
		Feet.	Feet.
Lake Superior	32,000	630	900
Lake Michigan	22,400	600	1000
Lake Huron	20,400	600	1000
Lake Erie	9,600	565	120
Lake Ontario	6,300	234	530

The estuary of this river enters the sea very obliquely. (The water being purified by subsidence in the lakes, it forms no delta.) It is 80 geographical miles broad at its opening into the Gulf of St. Lawrence, and contracts very gradually for 350 miles inland to Quebec. The communication along the chain of lakes is broken between lakes Erie and Ontario by the stupendous fall of Niagara, the largest and most magnificent, though far from the highest, in the world, the total breadth of the river (which is divided into two great cataracts by Goat Island) being 3225 feet, with a depth of descent of 162 feet in the one fall, and 149 on the other. The action of the water cuts back the cliff over which it falls at a supposed average rate of about a foot per annum, so that in 30,000 years it will

probably have worked its way up to Lake Erie. The sublimity of this fall is declared by all who have seen it, to be such as no language is adequate to describe.

(215.) The basin of the Saskatchewan, 300,000 square miles in extent, includes several large lakes, the chief of which is Lake Winnepeg; as does also that of the Mackenzie (441,000), within whose dreary confines lie the Athabasca, the Slave, and the Great Bear Lakes, visited only by fur hunters, or by those heroic explorers who, in the cause of science, have furnished examples of all but superhuman exertion and endurance.

(216.) The *European Rivers* are for the most part of very small magnitude in comparison with those of America. The largest are the Danube, the Dnieper, and the Don, the two former of which fall into the Euxine, and the latter into the Sea of Azof, and thus ultimately belong to the Mediterranean system.

(217.) The arid nature of the Spanish climate, and the small amount of snow in the Pyrenees, prevent the formation of any large peninsular river, for the Douro and Ebro, though considerable streams, cannot be said to merit that title. As little can any of the French rivers which flow westward. The waters of the Alps are carried northward by the Rhine, southward by the Rhone and Po, and eastward by the Danube, which receives all those of the Carpathian basin, the Tyrolese and Illyrian Alps—a total area of 234,000

square geographical miles. It is navigable nearly 1000 miles from the Euxine Sea, the last 400 of its course lying through the flat countries of Wallachia and Bulgaria, into which it enters by a rapid called "the Iron Gate," between Orsova and Gladova, through the Balkan mountains, immediately below the Pass of Kasan, cut by Trajan along the towering cliffs which descend to the water, in his first Dacian campaign, A.D. 103, and still bearing his inscription on the face of the rock. The total course of the Danube, windings included, is reckoned at 1494 geographical miles.

(218.) The north of Germany and Poland are drained by the Elbe, the Oder, and the Vistula, of which the former flows into the Atlantic, and the two last into the Baltic. The Elbe and Oder receive most of their waters from the most northern outliers of the Alpine system of mountains, and traverse a country considerably undulated and diversified; but the Vistula, with which commences the northern hydraulic system of the great Sarmatian plain, traverses, through almost the whole extent of it basin, a nearly dead level, full of lakes and morasses. The same may be said of much of the upper course of the Dnjeper, a river only remarkable as furnishing, by means of canals, a complete system of navigable communication between the Euxine and the Baltic Seas.

(219.) The most notable European waterfalls are those of the Rhine at Schaffhausen, not lofty, being only

70 feet in height, but very picturesque; those of the Velino at Terni, and the Anio at Tivoli, both artificial, but of exquisite beauty; that of Riukan Fossan, where the Maanelvan, a large river flowing out of the Miösvatn lake in Tellemarken, in Norway, springs 946 feet at a single leap; the Glommen Falls, and those of the Moxa, near Stav, in the same country. The Falls of the Clyde, in Scotland, are not wanting in grandeur or beauty. Those of Gavarnie (1400 feet) in the Pyrenees, and of the Staubbach (1004, as measured barometrically by the writer of this article) in Switzerland, are mere rills, remarkable only for their height, in which, however, both are surpassed by that of the Orco, a stream which springs 2400 feet from Monte Rosa, on the Italian side of the Alps (*Woodbridge and Willard*), and of which some further account would be desirable.

(220.) With exception of the Ural chain, as observed in art. 174, the northern portion of the Europo-Asiatic continent, from the Valdai to Kamtschatka, is one vast unbroken plain from the Arctic Ocean to the Altai—an area of 3,600,000 geographical square miles, through which, besides the Dwina, Indigirka, and Kolyma—no inconsiderable streams—three rivers of the first magnitude (the Obi, the Yenesei, and the Lena) deliver their waters into the Arctic Ocean. To form some idea of the excessive flatness of this immense region, and of that through which the Volga flows into the Caspian, it will

suffice to mention the heights above the sea-level of some of its more notable positions—viz., St. Petersburg, 0; Moscow, 363 feet; Tobolsk, 115; Perm, 370; Pinsk, 434; Casan, 57; Barnaoul, 383; Jakutsk, 268. Now, Tobolsk is situated on the Irtisch, a tributary of the Obi, and Barnaoul on the Obi itself, the one at 525 geographical miles, the other at 920 geographical miles direct distances from their respective mouths, which gives an average slope of the country in the one case of 8″·11, in the other of 4″·87. The Yenesei, after leaving the mountains, has, in like manner, nearly 800 miles to traverse, in a direct line, of a similar flat region, to the head of its estuary. Both rivers, therefore, in the lower part of their courses, are sluggish and monotonous, and, owing to the high latitude, desolate to the last degree in their features. The latter, however, in the superior part of its course from Yeneseisk upwards, has more the character of a mountain river. It derives a large portion of its waters from the lake Baikal, 1535 feet above the sea, a most romantic and beautiful mountain-basin, which is itself fed by the Selenga River, which carries into it the waters of the Tangnou, Kentei Khan, and Tschokindo. The basins of these great rivers respectively occupy 924,800, and 784,500 square miles, and their total lengths 2820, and 2800 geographical miles respectively.

(221.) The Lena takes its rise among the mountains

of north-east Siberia, on the northern and western slopes of the Daourian, the Yablouni, Udskoi, and Aldan mountains, from which it issues at Yakutzk, "the coldest of inhabited places;" thence to the sea its course is between banks of ice or frozen soil, which, where undermined in the summer, expose to view the carcasses (not mere skeletons, but with the skins, and even the flesh remaining) of extinct elephants, evidently adapted for inhabiting a cold climate, being covered with a thick coating of long shaggy hair—the flesh being in some instances so fresh as to have been devoured by dogs. The total length of the Lena is 2400 miles, and the area of its basin 594,000 square geographical miles.

(222.) The mountains which form the southern watersched of these rivers by no means alone separate the waters which run into the Arctic from those received by the Indian Ocean. Between these slopes is interposed that great continental basin spoken of in art. 137, which, however, owing to the peculiar aridity of its climate, has few rivers, and those for the most part terminating in salt lakes. The greatest of these are the Caspian Sea, and that of Aral—expanses of salt water, though less so than the ocean—the former of 140,000, the latter of 23,000 square geographical miles. Of these, the Caspian is fed by the Volga, one of the largest Russian rivers, which, with the Ural, drains the

south-western slopes of the mountains so called, and the flat steppe country from Moscow to Casan, entering the Caspian at Astrakan, after a course of 2400 miles. The Volga is admirably adapted for navigation, and by means of canals connecting its upper waters with the lakes Ladoga and Onega, near St. Petersburgh, forms a complete water communication between the Caspian and the Baltic by the Neva. The Aral Sea is fed by the Amu or Gihon River, which descends from the plateau of Pamir, and the Syr, or Sihon, which, breaking through the Bolar range, drains a somewhat similar plateau, of a triangular form between that range, the western extremity of the Thian-Shan, and an offset of that chain running in a north-west direction. Of this region scarcely anything is known, nor is our information much more complete respecting that portion of the great basin in question which extends from the Altai to the Kuen Lun, and along the axis of which, centrally placed, runs the whole length of the Thian-Shan, dividing the waters of the discontinuous salt-lake system, on its north side, from the more connected one of the lake Lop or Loph on its south.

(223.) To the south of this basin (which includes in its westward prolongation the whole of Persia, and which probably exists as such only in virtue of its aridity, since, had it a more humid climate, a great lake and river system would assuredly have been estab-

lished of west-flowing waters, communicating with the Euxine by self-cut channels), commences the river system of India, which consists of three gigantic rivers, the Indus, the Ganges, and the Brahmaputra (which carry off the waters of Upper and Central India, including the plateau of Malwa), and a number of smaller streams which drain the peninsula, the chief of which are the Nerbudda, the Godavery, and the Kistna, the former flowing westward, the two latter east.

(224.) The Indus is fed by the streams of the celebrated Punjab, or Five Rivers, from the lofty region of Ladak, the western and inferior portion of the Thibetan plateau (penetrated by the Sutlej to the lake Rewan), and the southern slopes of the Himalaya, as far east as the Peak of Jumnotri. These rivers, once free of the mountain intricacies, converge to and unite at a point near the southern extremity of the Suleiman mountains, after which the Indus receives no tributaries of any importance in the rest of its course (280 geographical miles), to Hyderabad, where it forks out into a delta 115 geographical miles in length, and 105 in breadth from Kurrachi to Kori,* whence it affords a free navigation up the country to Multan and Lahore, the current (except in the flood-season) running about a mile an hour. Its eastern

* We follow, in these Indian names, the Italian system of pronunciation as to the vowels, and as nearly as to the consonants as each case admits.

branches were early connected with the Ganges by canals for purposes of commerce and irrigation. Its total length is 1960 geographical miles, and its basin extends over 312,000 square geographical miles.

(225.) The Ganges receives by far the greater portion of its waters from the Himalaya range, from Jumnotri to the Lacheh Pass near Darjiling, east of which all the waters from those mountains flow to join the Brahmaputra. Very little of the plateau beyond the first range of the snowy peaks is drained by it, the whole of their northern slopes down to the level of the plateau being divided between the Sutlej (the eastern branch of the Indus) on the west, and the Yaru or Sanpi (a feeder of the Brahmaputra) on the east. In the western part of its upper course, its branches spread out like a fan, and collect not only the waters of the south Himalaya, but those of a great basin between the Aravulli, the Vindhya, and the Kymor ranges of mountains forming the plateau of Malwa. In fact, it may be considered as resulting from the union of "nineteen or twenty large rivers, of which twelve are larger than the Rhine," (Somerville). Its delta has already been noticed, art. 106. The floods of the Ganges commence, as already stated, in April, attain their maximum about the middle of August, and continue till October. The effect of the causes which produce them may best be estimated from the ratio of the water delivered per second at the maximum and at

the minimum, viz., 494,208 and 36,330 cubic feet respectively. The Ganges is remarkable for the great and rapid changes in its course in certain districts, by which it cuts away its banks in one part to add to them in others. Forty square miles (25,600 acres) are said to have been so carried away in one district, in the course of a few years.

(226.) The Ganges and Brahmaputra unite in a common delta, or rather in two deltas, distinct at their commencement, but which, in their prolongation seaward, have met and overlapped, presenting the form of an inverted M, the points turned inland. They drain a joint area of 432,000 square geographical miles; but the latter is by far the larger stream, its minimum delivery of water being 150,000 cubic feet per second (Wilcox), against 36,000 delivered by the Ganges. Its course is remarkable for the sudden turn it takes round the eastern extremity of the Himalaya range, after draining the northern slopes of those mountains, and the mountain valleys of the Thibetan plateau; a turn evidently corresponding to the sudden change in the direction of the upheaving forces acting at this point. Its floods are of immense volume; the plains of Upper Assam are an entire sheet of water, eight or ten feet deep, from the middle of June to that of September; and no wonder, when we consider that at one point (Cherra-pongi, in the Khasya hills) nearly 600 inches

of rain fall annually (*i.e.* in the six wet months). The upper course of the Brahmaputra is but little known, and the wanderings of its branches among the mountains east and north of Assam belong rather to speculation than to knowledge.

(227.) Before passing to the river systems of Eastern Asia, we must revert to that of its south-western area. The peninsula of Arabia is riverless as it is rainless, and it is not till we pass out of the reach of the tropical indraft of the north-east winds, that we find in the twin rivers, the Euphrates and Tigris, indications of a different set of conditions. These celebrated streams are supplied entirely from the Armenian and Kurdistan watersched, receiving positively no accession from the Syrian desert on their western side. They both run in a south-eastern, generally parallel course, to the head of the Persian Gulf, the Euphrates being the larger; and its upper waters curving round along the slope of the Armenian plateau, so as to inclose the upper basin of the Tigris. From Bir, in 37° N. lat., where it leaves the mountain country, it pursues a course skirting the eastern border of the desert, and for the last 700 or 800 miles from Kirkesia downwards, receives not the smallest tributary. Near Bagdad, it approaches the Tigris, within twelve miles, including between them the plains of Mesopotamia; and here, in those old historic times when Babylon and Nineveh were cities, and empire held its

seat in these now desolate regions, the rivers were connected by canals, which served the joint purposes of commerce and irrigation. Like the Ganges and Bramaputra, they have a common delta, which is supposed by many geologists (not without historical evidence in support of the opinion) to have been in great measure produced within the last 3000 years. The local circumstances are peculiarly favourable to the growth of a delta, the long narrow Persian Gulf allowing of no lateral sweep of the tides to carry off and disperse the deposited matter; and it is extremely probable that at some remoter epoch, but still quite within the *most recent* geological period, the Gulf occupied the whole of Mesopotamia to Bir and Diarbekir, leaving only a narrow but hilly isthmus at Scanderoon to connect Arabia with Asia Minor, as that of Suez connects it with Africa. At present, the Tigris sends out branches to the Euphrates from Amara, 150 miles from the mouth, but the complete junction of the rivers takes place 100 miles lower at Korna, from which to Bassora they form a single stream, subdividing again to form the modern delta. We now return to the river systems of Eastern Asia.

(228.) Each of the long and strait valleys which run southward from the breaking up of the Himalaya mountain system, between the ranges of the Cambodian peninsula, has its river, of which the chief are the Irawadi, the Martaban or Salwen, the Menam, and the

Meking or Cambodia, which water the Burmese empire, the kingdom of Siam, and the territory of Cochin-China. They are but little known to Europeans, with exception of the Irawadi, which has been ascended 450 miles from its mouth to Ava, the Burmese capital. It is a magnificent stream, delivering into the ocean no less than 350,000 cubic feet of water per second on an average of the whole year (of which 1-3000th part by weight is silt). Like all tropical rivers, it has its season of flood, during which its volume increases tenfold (from the minimum), running then with a velocity of $3\frac{1}{2}$ to 5 miles per hour. It enters the sea at Cape Negrais, through an extensive delta, which is prevented from spreading westward by the subaqueous prolongation of the chain of the mountains of Aracan, which goes to form the Andaman and Nicobar Islands, Sumatra and Java. There is reason to believe this coast to have been in a state of upheaval at least since the year 1750 and perhaps longer, though it is only from that date that positive evidence of changes of level are procurable. In the volcanic Island of Reguain, not far from the coast, three distinct steps of this process have been clearly pointed out.

(229.) The Chinese empire is watered by four great river systems, emptying themselves into the Pacific; the Hong-kiang, Tche-kiang or Canton River, the least of the four, and the Yang-tse-kiang, the Hoang-ho (or

Yellow River), and the Amur, all three of gigantic magnitude, the two former of which form what may be considered as a twin system, having a near approach to a common embouchure. The Yellow River derives its upper waters from the south-eastern border of the continental basin above mentioned, including the water-sched of the Thibetan plateau on its northern and eastern side, as also from the Yung-ling, Pe-ling, and Tapa-ling mountains, which traverse China from west to east, and direct its waters to the sea at Nankin through a course of 2900 geographical miles, and over a basin area of 548,000 square miles. Branches of the last-named mountains separate it from the Hoang-ho until near the sea, when they communicate in the low levels by innumerable canals; their mouths, however, being separated by an interval of about 90 miles, and by a delta the common produce of both. The Hoang-ho has a basin of 537,000 square and a course of 2300 linear, geographical miles.

(230.) The Amur takes its rise among the Daourian, Tschokindo, and Kiang-khan mountains, and the southern slope of the Yablonoi Krebet. It is a river of very peculiar interest as regards the progress of Russian domination in the direction of China, though little known to other than Russian explorers. It has a basin of 583,000 square geographical miles in extent, and a course of 2880 geographical miles, so that it is a river

system of the first order, and entering the sea at the very junction of the two great land-locked seas of Ochotsk and Japan, will assume, at some period in the world's history, a commensurate degree of political and commercial importance.

(231.) Among *African Rivers* the Nile is the only conspicuous one, and is in many respects the most remarkable river in the world,—as the seat of the earliest civilization, as a perpetual witness to the stability of those great natural arrangements by which the wants of one region are supplied by the superfluities of another, and as a geological chronometer by which some insight may be obtained into the duration of the existing order of things antecedent to history. Its ultimate sources are in all probability to be looked for in the mountains on, or adjacent to, the equator, and perhaps in the lake Ungiamesi. The main stream, the Bahr-el-Abiad or White River, has been traced as far as 3° 39′ N. lat., and may therefore very well derive its waters from snowy ranges, such as we know to exist in equatorial Africa, or from the lake above mentioned (which, be it remembered, is fresh), or from a generally boggy or lacustrine district, watered by equatorial rains; for there is reason to believe that during the sojourn of the sun north of the equator, the vapours of the Indian Ocean must of necessity be swept by the south-east trade over that precise district, and there precipitated in torrents

of rain. It is joined by the Blue Nile (Bahr-el-Azrek), which rises in the Galla country, south of Abyssinia, at Khartum, and by the Atbara, which traverses Sennaar at Goos, about the 18th degree of north latitude, from which point, in its farther passage through Dongola, Nubia, and Egypt, a distance of nearly 1300 miles, following the windings of the stream, it ceases to receive any accession of waters. Its course through Nubia is a succession of low rapids, called cataracts, at the last of which, at Assouan or Syene, it enters Upper Egypt. Hence it runs in a valley varying from 2 to 18 miles in breadth, through a succession of monuments of ancient splendour, to which the world affords no parallel, to its delta,—the mountains on either side being low ranges (decreasing in height from Assouan downwards) of granite, sandstone, and nummulite, but of which all the lower portions are buried beneath vast alluvial deposits brought down by the inundations. The Nile delivers at Assouan 24,000 cubic feet of water per second when at its lowest at the summer solstice, and 362,000 when at the highest in October (Horner, *Phil. Trans.*, 1855). Its *mean annual* delivery is calculated by M. Talabot at 101,000. At the time of the flood it is loaded with black mud of most fertilizing quality, to the amount of 1-633d of its weight, so that the total quantity of fertilizing matter spread over Egypt, or carried out to sea, is about 140 millions of tons. This immense deposit is

computed, from the evidence afforded by ancient monuments, the bases of which have been silted (not sanded) up, to cause a rise of the soil of the valley of 3½ inches per century. From borings made, at the instance of Mr. Horner, under the colossal statue of Rameses at Memphis, the true Nile sediment was found to terminate at 30 feet beneath the foundation of the platform on which the colossus stands, itself 10 feet below the present surface, which gives an interval of 10,285 years from the commencement of deposition at that spot to the age of Rameses, or a date of B.C. 11,646. At the depth of 39 feet a piece of pottery was found, which (unless subsequently buried there) must have dated its construction from B.C. 11,517 (Horner, *Phil. Trans.*, 1858). The supposed drainage basin of the Nile is 520,000 square, and its supposed total course 2240 linear, geographical miles.

(232.) The next African river in importance, as regards internal communication, is the Zambesi, Cuama, or Quilimano, recently explored by Dr. Livingstone, which enters the sea at Quilimane, in lat. 18° S., and, if really connected as he appears to consider demonstrated, through the Victoria Falls, with the Liba, the Liambi, the Luambesi, and an innumerable host of other rivers which cover the interior of south Central Africa like a vast network of anastomosing streams, drains an area of not less than 120 square degrees, or 432,000 square

geographical miles. The falls referred to are perhaps the most striking, after Niagara, which exist. The river, 1000 yards in breadth, is suddenly swallowed up in a narrow perpendicular cleft, 100 feet deep, in a black basaltic rock directly across its course, which is prolonged from the bank 40 or 50 miles, in which the river takes its new course compressed in a deep channel of 15 or 20 yards. The hydraulic system of the interior of South Africa, disclosed by Dr. Livingstone's researches, is anomalous in the extreme, and is only compatible with the idea of a generally level plateau, deluged with periodical rains, but not, like the plain of the Amazons, dominated by a great range of high lands on one side, with a slope to the other, but as if the periodical rains fell on a very gently rising convexity, so as to leave the waters undecided by what channels to seek the main arterial drainage. It would seem very probable that the cleft of the Victoria Falls has been of comparatively recent origin, and has determined a new system of drainage by which the water of those regions has been carried off more rapidly than heretofore, since the general tenor of Dr. Livingstone's narrative points to what may be termed a secular desiccation of the districts traversed by him.

(233.) The Niger, Joliba, or Quorra, rises in the Kong Mountains, and after running a considerable distance along their bases to the east-and-by-north, makes

a sudden turn at Timbuctoo to the south, and penetrating the chain of mountains, reverts to the west coast, and falls into the sea in the Gulf of Guinea at the New and Old Calabar, the extreme rivers of its delta,—streams foul and fetid, redolent of marsh poison and the moral pestilence of the slave trade. The expedition under Baikie, in 1854, has shewn the possibility of penetrating through this disgusting basin into regions full of tropical life, and exhibiting humanity under an aspect a few shades less repulsive than its savage forms for the most part assume.

(234.) Of *Australian Rivers* the catalogue is small, and, so far as can be at present ascertained, confined to very moderate distances from the coast. It would seem most probable that the central regions of that singular continent will furnish another instance of a "continental basin," with a system of internal drainage and salt lakes. Most of its streams flow in deep rocky clefts, affording no irrigation, and assuming alternately the impetuosity of torrents and the stagnancy of a chain of pools with a communicating thread of water sunk in deep gulleys channelled in a table-land. These streams rush with wonderful rapidity in the rainy season. The Hawkesbury has been known to swell to 100 feet above its usual level, sweeping away everything in its course. From Count Strzelecki we learn that the average fall of the rivers running eastward in the

colony of New South Wales, is 48 feet per mile, of those which run westward 9 feet, the land sloping inwards more gradually.

(235.) *Pampas, Silvas, Llanos, Prairies, Savannahs, Steppes, Tundras, &c.*—The mountains which constitute the central ridge of the old continent and the lateral of the new, tower to a vast height, while on their flanks, and after a more or less extensive interval of broken country and lower chains, they fall away into sloping sheets, terracing down by steps into the low lands, which ultimately flatten into what becomes at last an unvaried plain, extending to the borders of a far remote ocean. The easier accessibility of these regions, and in many cases their high fertility (formed as they have been by alluvial deposition from the washings of the higher ground), constitute some of them the principal theatres of human habitation; though it would seem that the higher developments of civilized life require something of the excitement and hardihood generated by the neighbourhood of at least a hilly country, and languish in the monotonous ease of an uninterrupted level, however adapted by its luxuriance for that material civilization which commerce fosters.

(236.) Each of the more extensive regions of this kind has some peculiar character due to its soil, climate, and the nature of its vegetable and animal tenants. Our limits forbid lengthened or minute description; but we

will endeavour, in as few words as possible, to convey some notion of the leading features of the principal among these flat regions.

(237.) *The Pampas of Patagonia* seem destined to perpetual desolation, not only by their climate (art. 274) but also by the nature of their soil, which terraces down in almost unbroken sheets of shingle and basalt, diversified with huge boulders, the whole brought down, no doubt, by ancient glaciers, and deposited by their melting when floated off to sea, and which occupy the whole eastern slope of the continent, from its extremity to the Rio Colorado. In these regions the vegetation is stunted, the winds fierce and tempestuous, and the population almost *nil*.

(238.) This desolate region is succeeded by one hardly less so, though different in its style of desolation. In the pampas of Brazil and Buenos Ayres, vast tracts are destitute of trees, and almost of water, but lying in a warmer latitude, and having, therefore, been exempt from the action of those causes alluded to in the last article, which have covered the alluvium with stony fragments, hardly a stone or a peeble is to be found in them for hundreds of miles. In this region, which extends southward from the estuary of the La Plata to Patagonia, and westward to the feet of the Andes, the alternation of the wet and dry season, acting on a soil composed entirely of red argillaceous alluvium, with

here and there calcareous concretions, effect no other variety than the growth and decay of gigantic thistles for some distance from the coast, replaced further inland by the long-tufted pampas grass, ranged over by innumerable herds of wild or semi-wild horses and cattle, whose skins are exported, and whose fat and dried flesh serves for fuel; and where, in the dry season, the pamperos (transient wind-storms from the interior) raise clouds of dust, involving the whole horizon in darkness so impenetrable, that even the lightning which accompanies them is only *heard* not seen. Roads there are none, nor any need of them. Lassoing a wild horse, mounting and riding him till he falls from fatigue, and is exchanged for another, the traveller, with his Gaucho guide, speeds on, day after day, and week after week, as for the bare life, towards the far-distant and long-invisible hills. The exciting gallop of Captain Head across this country, will probably be familiar to many of our readers. A tract of swamp and bog, succeeded by a region of ravines and stones, with a zone of thorny bushes and dwarf trees reaching to the Andes, complete the picture of this uninviting region, which communicates northwards, along the western slopes of the Parana Valley, with the hideous wilderness of the Gran Chaco traversed by the Salado, Vermejo, and Pilcomayo rivers, where the wild Indian still ranges in inaccessible freedom. The pampas of La Plata and Patagonia

together, are computed by Humboldt to occupy 135,200 square leagues, or 1,217,000 square geographical miles. If they offer little of interest on their surface, the buried, and in many cases hardly buried, gigantic remains of the Glyptodon, Mylodon, and Megatherium, with other singularly-formed monsters of an earlier Fauna, which they cover, amply compensate to the geologist for this deficiency by presenting him with the enigma of a once animated creation, which seems to have simply died out, without any of those geological cataclysms and catastrophes, or changes of climate, to which we are in the habit of attributing such events in general. It is somewhat singular, too, that among all these remains, few attributable to carnivora have been discovered, the most remarkable among them being the Machairodon Neogeum, Sabre-tusked Tiger, a truly dreadful form of fossil voracity.

(239.) The *Silvas of the Amazon River* include tract of perhaps not less than half a million square miles of the central area of South America, where, owing to the rich quality of the alluvium brought down by that river and its tributaries, and spread over the country by its inundations, aided, in the wet season by an immense rain-fall, and by the general heat of the climate, vegetation seems carried to the extreme of exuberance. A region more than six times the area of France, crossed by the equator, and reaching from the

cordilleras of the Andes to the mountains of Parimé, is clothed with a mass of forest, so dense and impenetrable as to defy access, except by navigation, and tenanted by innumerable wild animals, among which the monkey tribe holds a very conspicuous place. The descriptions given by Humboldt of this region, present pictures of forest life and scenery in which every feature of grandeur, gloom, and savage wildness is concentered.

(240.) *The Llanos of the Orinoco* occupy a perfectly level area of nearly 160,000 square miles, so level, indeed, that elevations of a few feet, quite imperceptible to the eye as slopes, suffice to form the watersched lines between adjacent streams. After the rains (during whose continuance the whole country is inundated) a rich pasture covers it, which has procured it, from the natives, the designation of the "Sea of Grass." This speedily dries and furnishes the material of extensive conflagrations, which, repeated year after year, effectually serve to maintain the treeless character of the region. The dust storms here are also terrific, and are admirably described by Humbolt (*Aspects*, p. 17).

(241.) About half the total area of North America, from the Alleghanies to the Rocky Mountains, including great part of Canada, Labrador and the Indian country to the north, to the amount of nearly 3,000,000 of square miles, has been characterized by Humboldt as "an almost continuous region of savannahs and prairies." The

terms, however, apply more correctly to those regions of the Great North American plain and flat river basins which are deficient in timber. These, however, differ much in climate, soil, and aspect. To the west of the Mississippi, where the ground rises in terraces towards the Rocky Mountains, the climate is arid, the soil sterile, often full of salt, and destitute, at all events, of fresh springs. The prairies of Texas, however, have a rich soil, a profusion of grass, and flowers of fine hues and delicate scent, and are adorned, not indeed with forests, but with frequent clumps of large trees, or here and there a single one of vast breadth of growth, covered with long pendent moss. To the east of the Mississippi, along the coast of the Gulf of Florida, extends a region of so-called Pine Barrens, where only trees of that family can extract nutriment from the sour sand. These are not confined to Alabama and Florida, but extend far inland, and occupy large tracts in North Carolina and Virginia. East of the Mississippi, the country, till cleared by the increasing population, was for the most part richly wooded, interspersed, however, with savannah and prairie grounds, the treeless character of which, as in the case of the Llanos, was perpetuated by frequent conflagrations, which swept across whole districts, and destroyed every living thing within their area. In the southern districts, the air, especially in the "bottoms," or low swampy regions bordering on the rivers, from

the heat and quantity of decaying vegetation, is impregnated with malarious miasma, producing ultimately, at New Orleans, the most virulent type of yellow fever.

(242.) The great northern plain of the old continent occupies an area of between 4,000,000 and 5,000,000 of square miles. From Belgium, through Holland (much of which lies actually below high-water mark), and North Germany and Prussia to the Vistula, we find a cultivated though sandy soil, with large tracts of heath interspersed, and presenting over all the area bordering on the North Sea and the Baltic, the phenomenon of granitic and syenitic blocks scattered in abundance, not uniformly, but in patches here and there, and referable as their origin to the older igneous rocks of the Scandinavian mountains—a phenomenon first brought into prominent notice by Deluc (*Geol. Travels*), and since recived as one of the chief supports of the "Glacier Theory."

(243.) At the Vistula may be said to commence the great Sarmatian, or East European plain, which, with exception of the Valdai Hills, extends from the Baltic to the Black and Caspian Seas, and to the Ural Mountains. It may be divided into three regions—a northern extending along the coasts of the Gulf of Bothnia and Finland, and the White Sea, and including all the region north of the Valdai to the middle of the Ural. Its climate, soil, and swampy character, admit but little

cultivation, and only a scanty growth of trees—chiefly birch and fir; while much of the ground is covered with a species of moss or peat called tundra, which reappears over all the northern area of the Asiatic continent where similar conditions prevail. The middle region of Russia is fertile and well watered, with a climate of only moderate severity, a soil of rich alluvial mould, admitting of high culture, a surface gently undulated, and extensive forests of pine, birch and deciduous trees. This region is surrounded to the south, by sandy, barren, and often saline *steppes*, which commence at the Dnieper river and extend along the Sea of Azof, including all the country north and east of the Caspian, and connect themselves by the desert of Kharesm, and the steppes of Kirghiz, Ishim, and Baraba, with the great Siberian plain north of the Altai. Nothing can exceed the dreary monotony of these steppes, wandered over by nomadic tribes—grassy indeed, and covered with flowering shrubs, tulips, and rosaceous plants for a few months, but parched by the sun and drying winds in summer, while in winter they become howling and shelterless wastes of snow. Some of these Asiatic steppes are covered with succulent ever-green articulated soda plants; in some, on the borders of the great salt districts, the salsola assumes a rich crimson or orange colour, giving a peculiar glow to the distant plains on the borders of salt lakes, while the plains

themselves glisten with flakes of exuded salt, like fresh-fallen snow.

(244.) In North Siberia winter reigns supreme. Beyond the 62d parallel corn does not ripen, and beyond this the fir forests intermix with and gradually give place to the tundra, among the swamps of which, buried or half buried, mammoth tusks, or rather those of the Elephas Primigenius (art. 221), occur so frequently as to constitute a very valuable article of search and commerce. These tusks, together with the skeletons of these and several other animals, form immense local accumulations, which become richer and more extensive the further one advances north. They are found in greatest abundance in New Siberia, and in the islands which fringe the borders of the continent between the Lena and the Indigirka, especially Lachow or Liakhoff, which is represented as almost wholly consisting of such remains. Hundreds of poods (40 lbs. Eng.) are thence extracted annually for exportation. They are frequent also in Kamschatka.

(245.) The great alluvial plain of China occupies upwards of 200,000 square miles, and is the seat of the oldest civilization of which we have any authentic account (sacred history, of course, excepted), and of actually the most numerous and condensed population anywhere to be found on the globe. It is for the most part a vast plain, crossed in all directions and irrigated

by canals, devoted wholly to culture, of which rice forms the principal article of produce, while the low hills afford tea to so vast an extent, that between 60 and 70 millions of pounds are imported annually into Britain alone.

(246.) The principal southern slope of the Asiatic continent is that of Central and Lower India, or the great plain of the Ganges and Indus, of which all the lower part is alluvial and of wonderful productiveness, at least under the influence of artificial irrigation. What may be called the Plain extends almost to the foot of the Himalayas, the slope of the Ganges (art. 196) being only one foot in 15,840. Benares, distant from Calcutta between 500 and 600 miles along the river, is only 270 feet above the sea. The valley of the Indus is sandy and barren, unless where artificially irrigated. On the east of the river, in its lower part, the plains expand into a sandy and desert district of many square degrees in extent, called the Thur, which is so low near the mouth of the river as to be overflowed by the tide, and incapable of cultivation. The Runn of Cutch, an extensive region, the coast line of which is laid down very differently in different maps, adjacent to the delta of the Indus, is supposed to be subject to frequent alterations of level from geological causes, one of which is on record so late as 1819, by which a considerable extent of what before was land was submerged, and a portion of the internal navigation of the country, which had been closed for

centuries, was again rendered practicable, while another part adjoining was permanently elevated.

Of Climates.

(247.) What we term the climate of a country is the result of all the meteorological influences to which it is habitually subject, and includes not merely the mean amount or intensity of the meteorological elements, but their distribution over the several months of the year and the several hours of the day. The mode of ascertaining exactly the mean annual amount and the laws of periodical fluctuation of these elements separately considered, of calculating them numerically, and representing the final conclusions to the eye by curves laid down in charts, is abundantly explained in the treatise on Meteorology referred to in sec. 16.

(248.) The elements which go to constitute our notions of climate, are chiefly temperature and moisture. These, indeed, are by no means the sole causes which affect vegetable and animal life. There are other elements, such as the greater or less habitual violence of the wind; solar light, as a vital stimulus, apart from the heat which accompanies it, and which stands in relation to the greater or less habitual obscuration of the sky by cloud; electrical manifestations; and lastly, barometric pressure, as a measure of the *quantity* of air taken up at

each inspiration of an animal, or present to a given surface of leaf in a plant, an element whose importance has been rather overlooked. All these constitute items in our estimate of a climate, and each of them, when present in a high degree gives it a marked character. But temperature and moisture exercise so preponderating an influence, that, in a general view of climates, we may limit ourselves to their consideration, regarding the others as subordinate, and their excess or deficiency as incidental and special causes of variety. Even thus limited, the number of cases which arise by simple combination of high, low, and medium annual averages, and of great and small annual and diurnal fluctuation (each of which exists as a reality over some more or less extensive region of the earth's surface), would become embarrassing. The diurnal fluctuations, however, assume importance only in two cases,—1*st*, When, as in the circumpolar regions, the year is divided into two very unequally illuminated seasons, and where the diurnal fluctuation in effect merges in the annual; and 2*dly*, at very great elevations in or near the tropics, as in the Bolivian and Thibetan plateaus, where, owing to radiation in clear sky and rarefied air, the difference of night and day temperature becomes excessive, and where the nightly dews perform the office of rain, and supply its place.

(240.) Elevation above the sea-level exercises a

peculiar influence on all the elements of climate. As we rise above that level, the temperature sinks at the rate of a degree for every 350 feet of elevation, and of course the mean temperature of the year is affected at an elevated station to that full extent. Thus it happens that in ascending a mountain from the sea-level to the limit of perpetual snow, we pass through the same series of climates, so far as temperature is concerned, which we should do by travelling from the same station to the polar regions of the globe; and in a country where very great differences of level exist, we find every variety of climate arranged in zones according to the altitude, and characterized by the vegetable productions appropriate to their habitual temperatures. The amount of rain, too, is very greatly dependent on the level of *the soil*. It increases on mountain slopes exposed to moist winds, up to a certain level, different in different geographical districts, and then diminishes, in virtue of the general law of hygrometric siccity in the upper regions of the atmosphere. At great elevations, too, the force and direction of winds, and the amount of cloud, are often very different from what prevails below. Thus, on the Peak of Teneriffe, the summer wind is habitually S.W., and the sky almost always cloudless, while at the foot of the mountain the N.E. trade prevails, and a dense stratum of cloud covers all the surrounding ocean. Not only the amount, too, but the *quality* of solar radiation is

affected. The chemical rays of the spectrum are powerfully absorbed in passing through the atmosphere, and the effect of their greater abundance aloft is shewn in the superior brilliancy of colour in the flowers of Alpine regions. Nor can the difference of density in the air itself be devoid of influence either on plants or animals. Dr. Mühry, in a work of great merit recently published (*Klimatologische-Untersuchungen*, Leipzig, 1858), informs us, for instance, that among the inhabitants of very elevated regions, pulmonary phthisis is a disease unknown.

(250.) *Distribution of Temperature.*—The law of distribution of heat over the earth's surface is represented to the eye by the systems of Isothermal, Isothēral*, and Isocheimōnal lines described in METEOROLOGY, art. 149, which severally connect those points of the globe which have equal *mean annual, mean summer*, and *mean winter* temperatures; the important points as regards climates being, that these several sets of lines are not coincident (except locally and accidentally), so that, even as regards temperature alone, it is rare to find two places that have the same annual average, and also the same distribution of heat in the several months. How this may affect climate will be obvious, if we consider the cases of two places of the same mean or average temperature, which in the one is maintained nearly uniform throughout the

* See the treatise already cited.

year, while in the other a burning summer is compensated by a rigorous winter.

(251.) If the sea covered the whole earth, or if it were uniformly occupied by land, there would prevail in all regions a climate dependent wholly on the latitude of the place, and on the sun's declination at different seasons. What would be the exact mean temperatures, and the exact annual fluctuations corresponding to each latitude in either case, it is needless to inquire; but it is certain they would be very different in the two cases, by reason of the different relations of land and water to heat. But if we take an average of the actual mean temperatures corresponding to each degree of latitude all round the globe, we shall obtain a mean law under the actual state of things which may be called the *normal law* of mean temperature, and which is not very inaptly represented by the formula—

$$41^\circ{\cdot}8 + 39^\circ{\cdot}7 \times \cos.\ (\text{twice latitude}):$$

and by attaching to each parallel of latitude a number expressing the temperature computed from this, there would arise a *system of normal isothermic lines*. The actual system, as may be seen in Plate II., deviates much from this regularity; and the manner of this deviation, which constitutes the first and greatest basis of distinction between the heat-climates of the globe, is not a little remarkabl

(252.) Mr. Dove has constructed a chart, in which

places which have the same excess above, or defect below, the normal mean temperature, are connected by lines which he terms Isabnormal lines—the order of the lines corresponding to the amount of deviation; and on an inspection of this chart, three very prominent features are apparent. 1*st*, that the lines which limit the regions into which the globe becomes thus divided, or the lines of normal temperature, do not, as would at first sight appear probable (and as would be the case had the earth no rotation on its axis), follow meridional directions, but are *systematically* oblique to the equator, being directed from N.W. to S.E. 2*d*, That they divide the globe into two hot and two cold regions, in the form of broad belts, whose medial lines have a generally similar direction, and which, so far from being emphatically regions of much land and of much water, run systematically *across the great masses of both.* Thus, the principal hot region includes nearly all Australia, the Indian Ocean, India, and all south-west Asia and east Africa, Europe, and the North Atlantic; and the principal cold one, the western half of South America, the south-west equatorial, and north-east Pacific, and all east Asia, from Cochin-China northwards. The other hot region includes the S.W. Atlantic, all the eastern side of South America, and the Caribbean Sea, and (after a small interruption or suspension) springs over to the other side of the American continent, to reappear in north-west America and

the North Pacific, while the other cold one takes in west Africa, the south-east and equatorial Atlantic, and all the east side of North America. *3dly*, That these regions, so distributed, bear evident reference both to the situation of the coast-lines of the great land-masses and to the trade-winds. To make our meaning clear, we will suppose the globe divided, not by the true geographical equator, but by the tropic of Cancer (which may be considered as the medial parallel of the land, and to which, rather than to the true equator, the sources of heat-disturbance have reference). Land lying to the north of this being considered as *northern*, and to the south, *southern*, it appears that, in the *northern* masses, the regions in which the temperature is in excess occupy their western, and in the *southern* their eastern coasts, while the reverse rule holds good for those in which it is deficient. A comparison of this rule with what is above stated, in reference to the regions themselves, will verify its enunciation in these terms.

(253.) So stated, the cause is not far to seek, and it is one of a generality commensurate to that of the observed facts. Referring to our account of the oceanic currents as traced in arts. 51-65, we see—That the hot water of the equatorial currents in *all* the seas is dashed against the *eastern coasts* of *southern masses*, while the cold supplying currents from the southern ocean, sweep along the west sides of those masses; that, in its

northern circulation, the hot water is carried across the great oceans north-eastward, to strike on the west sides of the *northern masses*, while cold return-currents flow down their east sides; and that, in its southern circulation, the hot water is thrown off southwards by the eastern coasts of the southern masses. The only point which remains unexplained in the view here presented, is a small breach of continuity in the hot region between the Caribbean Sea and the north-west coast of North America, where the two cold regions run together across it over Mexico. It should also be observed, 1*st*, That though the immediate influence of these causes is greatest on the coasts, their prevalence extends deep into the continents, being propagated onwards by the winds; and, 2*dly*, That the inequality now in question is independent of another law more general still in its enunciation, though of smaller influence, viz., that the whole northern hemisphere is, on a general average, 3½° warmer than the whole southern, as containing more land to be heated by the sun when north of the equator.

(254.) Within each of these four great geographical regions the mean temperature increases or decreases (according to the character of the region) from the borders towards the middle, and each of them has within it certain poles or foci (which may be called poles of relative warmth and cold), at which the peculiar character of the region is most conspicuous. The prin-

cipal, or Europo-African Hot Region, for instance, is separated from the cold region to the west by a normal line running in an undulating curve from Baffin's Bay to the Cape of Good Hope, and from that on the east, by one commencing opposite Nova Zembla, dividing Europe from Asia almost conterminously as far as the Caspian Sea, and then passing off south-eastward to the Philippine Islands, and across the South Pacific. Within this area the north *pole of relative warmth* occurs almost precisely on the Arctic circle in long. 4° east, between Iceland and the Norwegian coast (full in the sweep of the Gulf-stream drift). At this point the mean annual temperature is *fully* 20° *above* that which would be due to its latitude on the supposition of a normal climate, and in receding from this point as a focus on all sides, the excess of mean temperature decreases so as to mark [illegible] a series of ovals, the interior of each of which is [illegible] warmer than those outside. Thus, the oval of 18° [illegible] just grazes the North Cape; that of 12° takes in the whole coast of Norway and the north of Scotland; that of 9° the whole of Britain, the French coast (including Paris), Holland, Denmark, the greater part of the Baltic, and the Gulfs of Bothnia and Finland (just excluding Petersburg), up to Archangel; and, lastly, the [illegible] excess cuts the coast of Greenland at Cape Farewell, passes nearly through Madrid and Algiers, crosses Sicily, Calabria, Hungary, and Russia, and includes all the

capitals of Europe. In the southern hemisphere there is no very prominent focus of this kind, but a point in 30° S. in the meridian of Madagascar, just where the warm currents of the Indian Ocean unite after rounding that island on their way to the Cape, offers a feeble and rudimentary one.

(255.) The east Asiatic cold region has a strongly-marked focus of relative cold at Yakutsk, where the deficiency of annual temperature amounts to −15°, and round which, in all directions, this deficiency decreases, over a series of ovals, of which that of −7° includes the whole of north-east Siberia, from the mouth of the Jenesei to that of the Kolyma, and descends south through the Baikal Lake and Ochotzk into Chinese Tartary. Continued south across the Pacific, this region, as above stated, enters upon the west coast of South America. Off that coast, at 300 or 400 miles south-west of Lima, in lat. 15° S., long. 82° W., occurs another very well marked focus of the same character, but less intense, the deficit of temperature being only 9°. The oval of −7° about this focus enters on the South American coast, and includes Lima, which thus (owing to the refrigerating power of Humboldt's current, to which this focus is clearly referable) enjoys a far cooler climate than its proximity to the equator would otherwise entail on it. In the Pacific, in lat. 20° N., long. 225° E., is also the central point of a small subordinate oval of relative

cold (of about $-2°$), a feature which we shall have occasion to notice in another part of our subject.

(256.) The next, which may be called the American Warm Region, has its northern focus in the Pacific, in lat. 56° N., long. 141° W., not far from Sitka, in Russian America. It is far less strongly developed than the Atlantic focus of a similar character, its excess of temperature being $+9°$, and its influence on the continent of America is very limited, but nevertheless sufficient to afford the whole coast, from Vancouver's Island northwards to the Aliaskan peninsula, a climate 7° warmer than the normal one, an advantage equivalent to that of a transfer from North Iceland to New Halifax, and which forms a most important consideration as regards the future fortunes of the new colonies of Vancouver's Island and New Caledonia. In the southern hemisphere we find no marked indication of a corresponding focus, which is perhaps owing to a deficiency of the requisite observations. Owing, however, to the large portion of this hemisphere occupied by sea, the warmer areas by no means stand in so strong a contrast to the colder, as in the other.

(257.) The last of these regions we have to notice is the American cold region. It is very strongly marked, and distinctly so even in its prolongation into the southern hemisphere. In the northern continent it has a focus of relative cold in lat. 65° N., long. 96° W., near

Wager Inlet, at the north-east corner of Hudson's Bay, whose intensity (– 13°) nearly equals that of the Siberian focus, and whose influence is very great over the whole north-east portion of the continent, affecting Quebec with a mean deficit of 6½° (equivalent to a transfer from the south of England to the Orkneys), and even New York by one of 4°. In the southern hemisphere there is a sufficiently well-marked focus of the same character, and which bears nearly the same relation to the south-east coast of Africa that the focus of Lima does to South America, being only rather less intense (–6°), and not extending its influence very materially on the continent. It is, however, precisely on the spot where, from the indraft of cold water from the southern ocean, we should expect to find it.

(258.) The extreme cold of north-east America is evidently referable to the delivery of the whole circulating water of the Arctic Ocean, together with all which is introduced through Behring's Straits along its coast, and through the intricacies of Baffin's and Hudson's Bays, and the channels leading into them, deep into the continent, and among its outlying appendages. That of Siberia, and east Asia in general, is not so obvious a result of Oceanic causes. It arises rather from the extension across Asia of the lofty mountain-chains between the 30th and 40th parallel, which increase the rigour of winter to the countries north of them, by

intercepting the south-west anti-trade, and obliging it to deposit its moisture on their summits, thus draining it of its latent heat, which would otherwise be given out to the plains beyond in rain or snow.

(259.) The deviations of the isothēral and isocheimōnal lines from each other, and from the annual isothermals, or the exaggerations of the annual fluctuation of temperature at any place, refer themselves quite as *obviously to a prevalence in its neighbourhood* of great tracts of land or of water, and are, in fact, where not accounted for by special and local causes, no other than thermic expressions of its more or less approximation to a "continental" or "insular" situation. (See the treatise on METEOROLOGY, above cited, art. 40.) As instances of purely insular climates, we may take those of the Azores, where the difference of mean summer and winter temperatures is only 8°; at Bermuda, 13°; in the Friendly Isles only 2°; at St. Helena, 9°. As examples of continental ones, we find at Prague a difference of 29°; at Tiflis, 44°; at Astrachan, 61°; at Orenburg, 63°; and at Yakutsk no less than 102°, the *mean* winter temperature there being − 40°, and the summer, + 62°. In the interior of North America we find this difference carried not quite to so great an extent, but still far beyond what prevails over the whole of Europe, amounting to 44° at Philadelphia and Washington, and to 54° at Fort Snelling, in latitude 44° north, and longitude 94° west; the

winter temperature being − 14°, and the summer + 68°; while at Florence, in the same latitude, the corresponding temperatures are 41° and 74°.

(260.) The difference between land and sea climates in this respect tells upon the general average of the whole earth, the northern hemisphere having so great a preponderance of land. By comparing the results of registers, in positions adapted for the purpose, Mr. Dove has arrived at the remarkable conclusions that the mean summer temperature (July) in the whole northern hemisphere is 70°·9, and in the southern (January) 59°·5 —while the winter means for the two hemispheres (respectively January and July) are 48°·9 and 53°·6—giving to the whole earth an average surface temperature of 58°·25, with an average excess of 8° in July, a kind of general summer, due to the cause above mentioned, and which would be even more influential were it not partly counteracted by the greater proximity of the sun to the earth in January.

(261.) Mr. Dove calculates the *mean* temperature of the whole terrestrial equator at 79°·8, and that of the north pole at + 2°·2, and the mean summer and winter temperatures at the poles at + 30°·6 and − 58°·6. It hardly need be observed that the extremes of absolute temperature over the globe vary within much wider limits. Sir C. Napier records a temperature of + 132° in the shade in Scinde in June. A *midnight* temperature

of [illegible] has been observed in the northern Circars of India (Thomson). On the other hand, Dr. Kane records −67° in January and February at Rensellaer Bay (78° 38′ N. lat, 71° 41′ E. long). Captain Back, at Fort Reliance, observed −70°, and Gmelin, at Kiringa, in Siberia, has recorded an observation of −120° (Thomson). *The difference of the extremes is 252°, which exceeds by 72° the whole interval of Fahrenheit's scale between the freezing and the boiling points of water.*

(262.) The isotherm 32° F. limits the region round the pole at which (below a few feet from the surface) the soil may be expected to be found habitually frozen. The course of this isotherm, as drawn in K. Johnston's Physical Atlas, is as follows:—

Longitude.	Latitude N.	Longitude.	Latitude N.	Longitude.	Latitude N.
Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
0	71½	120	49½	240	56½
30	70	150	53	270	50½
60	60	180	58	300	53
90	51¾	210	62¾	330	64

(263.) The line descends then, in the two continents, to nearly equal latitudes (50°). The places where this takes place are at Irkutsk, on the Baikal Lake, and at the southern extremity of Hudson's Bay. The latitude is about that of Cornwall, whose mean temperature is 52°. At Yakutsk the soil is frozen to a depth of upwards of 630 feet, and would be so no doubt to a much greater depth, but that the prevalence of hot

springs about that region (Atkinson) indicates a subterranean source of warmth. Throughout Russia and Siberia if we put confidence in the conclusions of M. Kupffer, there would seem to exist some internal cause of disturbance in the temperature of *the soil*, as distinct from the mean temperature of the air above it.

(264.) The line of maximum mean temperature, or the thermic equator, by no means coincides with the true equator. Over a great part of the Pacific, indeed, and in Mid-Atlantic, it does so pretty nearly; but in those longitudes which include the great masses of land, it deviates northward, crossing South America in about 5° north latitude; and in the 180 degrees of longitude, which include all the eastern world, from the west of Africa to the east of Australia, it approximates much more nearly to a great circle, inclined at an angle of 15° to the equator, and crossing east Africa, Arabia, and the peninsula of India nearly in that latitude north.

(265.) *Distribution of Moisture.*—In considering this branch of our subject, we must distinguish between hygrometrical moisture, which exists as vapour in the atmosphere, and is ready to be deposited in dew at night, and that which falls in rain or snow. The former is always present to a considerable extent, at least within a few hundred feet of the sea-level, and in its average amount (under that condition) is regulated in great measure by the mean temperature of the place. To such an extent

is this the case, that, with the exception of four places (Hobartown, Madrid, Tiflis, and Washington, the three last of which are obviously exceptional, and influenced by very special and local causes),* the mean pressure of aqueous vapour at all the stations (21 in number) in all latitudes, set down in the list of carefully determined ones, at the end of the treatise on METEOROLOGY already referred, will be found to be represented by the formula—

$$0{\cdot}067436 \text{ in.} \times (1{\cdot}032075)^t$$

(Where t is the mean annual temperature in degrees of Fahrenheit), within limits hardly exceeding the difference between the mean results of successive years for each. It increases rapidly therefore in approaching the equator from the poles. The *relative humidity* of the air, however, or the proportion of its vapour to that of saturation, on which depends what is commonly called the *moisture or dryness* of the air, or, its evaporating power, is much less dependent on local situation; and, with certain remarkable exceptions, may be taken, on a general average, as about 0·75, or three-quarters of complete saturation at the mean temperature.

(266.) The laws which regulate the distribution of rain (including snow, hail, etc.) over the globe are more complex, and its amount, both average and occasional, subject to much greater local deviations from a normal quantity depending on latitude than either heat or

* Philadelphia is normal.

hygrometric moisture. Generally speaking, the average rain-fall of the year is greatest at the equator, and diminishes rapidly, but very far from regularly, in approaching either pole. The average annual rain-fall over the whole globe has been roughly estimated at 60 inches, or 5 feet in depth—between the tropics, 96, and in the temperate zones, 35; that is to say, 37 for the northern hemisphere, and 33 for the southern. In high latitudes, where unaffected by abnormal causes, it is much less,—thus we find an average of only 13 at Uleaborg, and 17 for Petersburg.* When we consider, however, that regions of several millions of square miles in extent exist not far from the tropics, in which the average of rain is *nil*, while in others it amounts to 200, 300, and even 600 inches, we see that it is an element to baffle all exact calculation, and that all that can be done is to indicate the sort of local conditions favourable or unfavourable to a high average.

(267.) The favourable circumstances, besides proximity to the equator, are,—1*st*, and within certain limits, elevation above the sea-level. Thus we find for the non-mountainous districts of Europe an average of 23 inches, and for the mountainous ones 42. The influence of this condition, however, diminishes beyond a certain

* These particulars, as well as many of the data, and much of the general statements which follow, are taken (or concluded) from Mr. Keith Johnston's excellent synopsis of this subject.—*Physical Atlas.*

height, which is not the same in all countries, varying from 2000 to 7000 or 8000 feet. Nor is it absolute, but depends much on exposure and on the general configuration of the soil. Thus an elevated and extensive table-land, like the interior of Spain, receives less rain than the plains around it, the current of vapour-bearing wind being tossed up into a higher region after travelling up its slopes, and in so rising, precipitating its moisture. To give the rise of level its full power, a slope increasing in steepness, and facing the moist wind (whichever that may be), is requisite. A table-land surrounded by mountain ridges overtopping it (such as Thibet, Bolivia, and Utah), is necessarily arid.

(268). *2dly*, Exposure on the sea-coast to warm winds blowing from the sea. These, in the temperate zones, are the anti-trades. West coasts, then, are rainy in these zones, in comparison with east. The mean annual rain on the west coast of England and Scotland is 45 inches, according to Mr. Keith Johnston, while the average for the east coast is only 27·4 inches. This is among the most prominent and general influences. If the west coast be a high one, and especially if the sea adjacent to it be habitually warm, it is carried to a maximum. Thus we find along the northwest coast of America, from Sitka to Vancouver's Island, and along our own west coasts and that of Scandinavia, an annual amount of rain far beyond that which might be expected

from the latitude. The average for Sitka (lat. 58°) and for Bergen (lat. 60°) are each of them 88 inches, which for so high a latitude, is enormous. Now, both these stations are in close proximity to the northern "foci of maximum relative warmth," which is situated at sea to the westward in either case (arts. 254, 256). The west coast of Patagonia is also remarkable for deluges of rain, but being in the immediate proximity of the principal focus of maximum relative *cold* in that hemisphere, the rainfall is chiefly confined to the winter months, whereas in the northern stations it occurs indifferently at all seasons.

(269.) Between the tropics the rains are periodical, and closely accompany the progress of the vertical sun. In India, however, it is the monsoon which blows *on* the coast, and not the position of the sun, which determines the rainy season. This sets in on east coasts with the north-east monsoon (April to October), and on west with the south-west (October to February). The region of the monsoons extends over China, and there it is the north-east monsoon (that which blows over the north-west Pacific) which brings the rains.

(270.) Influences unfavourable to rain are—1*st*, Situation under the lee of high land intercepting the vaporiferous winds. Exposure on east coasts in the temperate zones, and on coasts remote from the monsoon in India, is one form of this condition. It is carried to its extreme

when immense and lofty mountain chains, rising through half the atmosphere of air and much more than half that of vapour, intercepts the latter in its progress towards them, and effectually drains the winds of their moisture. In such cases, when the lee-country is at a comparatively much lower level, the descending wind, having parted with its vapour, and acquiring warmth by condensation, becomes arid and parching. *2dly*, Exposure to the indraft of trade-winds coming in from a *colder* region. This influence is carried to a maximum when such winds, to arrive at the place, have to traverse much land and little sea, the supply of moisture being less. Even in the open ocean, as we have seen (art. 20), little or no rain falls within the sweep of the trades. *3dly*, Absence of vegetation in warm climates, and especially of trees. This is no doubt one of the reasons of the extreme aridity of the interior of Spain. The hatred of a Spaniard towards a tree is proverbial. Many districts in France have been materially injured in respect of climate by denudation (Earl of Lovelace *on Climate, etc.*), and on the other hand, rain has become more frequent in Egypt since the more vigorous cultivation of the palm-tree. A sandy or rocky soil is no less influential in producing aridity.

(271.) *Rainless Districts.*—Commencing within a small distance of the coast of Morocco, and including all the north of Africa (except Tunis and Algeria), Syria

the northern half of Arabia as far as the 20th degree of latitude, and almost the whole of Persia, extends a zone of an average breadth of 900 geographical miles, in which rain is altogether absent, or of very unusual occurrence. With a narrow interruption, where the chain of the Himalaya passes into that of the Hindu Kho, and which includes Afghanistan and the Upper Punjab, this zone is prolonged north-east through Thibet, Upper Tartary, and into Mongolia, expanding somewhat in breadth, under the name of the Deserts of Gobi and Shamo. (In Africa it is known as the Sahara, and extends southward, when widest, nearly to the 15th parallel). It is thus broken into two great rainless districts, the one comprising about three millions, and the other nearly two millions* of square miles, which exist as such under widely different conditions both geographical and meteorological, the separation between them being strongly indicative of this diversity.

(272.) *Deserts of Gobi and Shamo.*—The aridity of this region is of very easy explanation. It unites in perfection all the conditions of dryness. It is fully within the sweep of the north-east winds drawing in from Siberia towards the sun when vertical over the burning plains of Hindostan, with an immense region

* By a rough measurement, as laid down in K. Johnston's *Physical Atlas* (allowing for the projections). As usually stated, the areas are much less. Humboldt made the Desert of Gobi, with Thibet, only 549,000 square miles.

of land to windward. It is sandy or rocky, and treeless; and it is completely cut off from receiving any rain from the anti-trades in the winter half of the year by the barrier of the Himalaya.

(273.) *Deserts of Africa, Arabia, Syria, and Persia.*— I. During the months when the sun is north of the equator, the whole of the region occupied by these deserts is within the sweep of the N.E. trades, which, it will be borne in mind, extend over continents to a far wider range from the equator than at sea; both because the medial line of heat follows the sun more closely, and therefore oscillates within wider limits of latitude; and because the heat itself on and adjoining to that medial line is greater. These winds, in arriving at Arabia, Syria, and Persia, have travelled almost entirely over land. Those which arrive in Africa, it is true, have traversed the Mediterranean; but this is a narrow sea; and we have already seen† that even the ocean cannot supply vapour enough to saturate the continually-increasing thirst of these winds. II. When the sun is south of the equator these regions lie within the district of the anti-trades, and being under no intercepting influence, might be expected to receive rain. But the winds can only deliver what they have taken up and not re-deposited. Now, if we trace (as in the annexed figure) the course of any parcel of air arriving from any part of the dry region at the medial line of heat (indicated

† art. 20.

at its greatest southern limit by the dotted line) as a surface or trade-wind (following, that is, a parabolic or hyperbolic curve having its vertex on the equator), indicated by ↘, and returning as an upper current along *the same track reversed* ↖, until it shall return to the surface

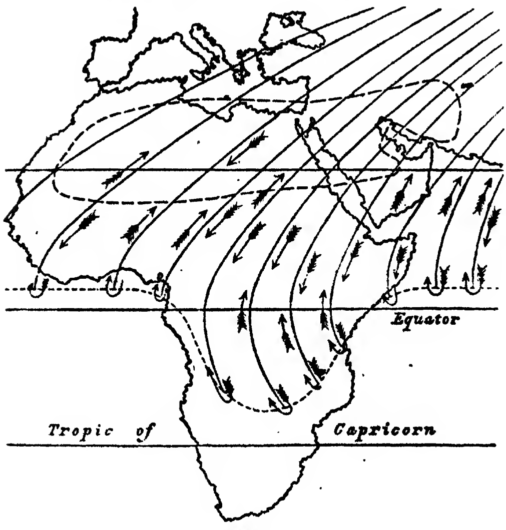

Fig. 1

as an anti-trade, we shall find it to lie wholly, or almost wholly, over intertropical land, and that land hot and dry, for its moisture has been *continually swept upwards towards the hottest line* in the southward progress of that line, and continually discharged upon it in torrential

rains, much more copious, and therefore more exhausting, than the equatorial rains at sea, by reason of the greater elevation attained under the influence of more intense heat. The consideration of the figure will sufficiently explain any point left unsaid. The reader will observe that we decline adopting the doctrine recently propounded of a systematic crossing of the south-east and north-east trades at the medial line. In so doing we are no way disturbed by the phenomenon of infusorial dust of South American origin which occasionally falls on the north-east of Africa. Such dust might be taken up by winds tracing in inter-tropical South America precisely the same parabolic courses as these in Africa, and carried in their return northward as an upper current across the Atlantic. A good portion of "South America" too—all the sultry Llanos of the Orinoco, in which much infusorial dust, the dried residuum of the inundations, might be produced and whirled aloft, lies north of the equator.

(274.) The west coast of Peru and Bolivia, as far as the 30th parallel, is rainless, as is also very nearly so the plateau of Mexico and the west coast of Guatemala. These lie within the region of the trades, and though these sweep over sea as regards Mexico, any rains they may bring are discharged on the eastern slopes of the mountains which receive them. A similar cause, reversed in the direction of its influence, deprives the

eastern side of extra-tropical South America of rain, which the Patagonian Andes almost completely intercept, as brought from the Pacific by the north-west anti-trades. California, Utah, and the countries under the lee of the Chippewyan mountains, are, in like manner, hindered of their due supply from the south-west anti-trades, which is discharged on the western slopes of the coast ranges.

(275.) South Africa, though arid, yet as it receives both the trades and the anti-trades from over wide oceans, is not condemned to that extreme of siccity which characterizes its northern region. The west coast receives a great deal of rain from winds sweeping over the warm water of the Mozambique current, drawn inland by the proximity of the heated interior of the continent, and discharging their moisture on the coast ranges of Zanzibar and Mozambique.

(276.) Snow never falls at the sea-level between the tropics. Canton, just on the northern tropic, has been occasionally astonished by a snow fall. In the southern hemisphere the limit is more remote from the equator—Sydney (lat. 36° S.) and the southern parts of the Cape Colony, as far as the 32d parallel, lie within its occasional range.* In the north Atlantic it hardly attains so low as 45° of latitude.

* On the continent of America it has been known to fall at Buenos Ayres (33° S.)—*Edin. Phil. Trans.* vi. 387.

(277.) The transition from an inter- to an extra- tropical climate, as regards the fall of rain, is characterized by a very marked change in the season of the rains. In the former, as we have seen, torrential rains accompany the sun in its approach to the zenith. In the latter, on the contrary, the regions adjacent to the tropics are visited exclusively, or chiefly, by rain in the winter months. The reason is obvious. In the former case the rains are those which fall on the first elevation of the vapours into the higher region of the atmosphere, and therefore occur vertically, or nearly so, over the place where that happens. In the latter, they are the *first rains given out by the residual vapour on the descent of the upper current to the surface* as an anti-trade wind, and are, so, periodical in another sense, owing to the fluctuation of the limit between the trades and anti-trades. In open ocean, under the equator, or rather from 4° to 9° north, there is a zone in which it rains heavily, and almost daily, in the afternoon hours, the rains being accompanied with frequent and violent electric discharges, while the nights are serene and cloudless. In the higher atmosphere, between the levels of the upper and under current, occurs a calm stratum which, over the sea, is almost always uniformly and densely clouded.

Distribution of Thunder-Storms, Hurricanes, and Earthquakes.

(278.) The explanation of these phenomena, as physical facts, belongs to the departments of Meteorology and Geology as bodies of science. Their distribution and greater or less intensity and frequency in different regions of the earth, with reference to the local conditions and peculiarities on which these depend, however, form part of our present subject. As electricity is accumulated during the evaporation, and discharged in lightning during the rapid and copious condensation of moisture, we should expect to find thunder-storms most frequent in those regions where, owing to any general or special cause, the condensation of vapour is frequent and sudden, and least so where moisture is most copiously and continually abstracted from the surface by evaporation, with but little return in rain. And such is the case; for it is observed that in those parts of the ocean over which the trade-winds sweep, thunder-storms are very unfrequent, while in the zone of the equatorial rains from 4° to 9° north latitude, where the first and most copious discharge of the up-cast vapour takes place, and where the clouds form rapidly, and hurry to their resolution at regular hours of the day in rain, electric discharges are exceedingly frequent and violent. So also the setting in of the rainy monsoon, in

the monsoon countries, is ushered in with violent thunder-storms, and so in certain localities, where, during certain seasons, and at regular hours of the day, clouds collect and rain falls copiously (as in the mountainous parts of Jamaica, and in certain valleys leading off from the Lake of Como in Italy), thunder-storms occur daily during the hottest season.

(279.) In the Polar regions, both arctic and antarctic, thunder-storms are of very rare occurrence, a sufficiently copious supply and sudden condensation of vapour being wanting. M. Geisecke, who resided six years in Greenland, only heard thunder once (*Mrs. Somerville*). Thunder-storms, too, are unknown in the rainless districts of Peru and in California (*Gibson*), under the lee of the coast-ranges of mountains, which, at the same time that they condense the clouds, attract and carry off the atmospheric electricity. Generally speaking, they are more frequent on mountains than on plains. About forty per annum are reckoned to occur in Greece and Italy, and about twenty-four on the coasts of the Atlantic and in Germany (*Mrs. Somerville*). In the United States they are more frequent and fatal than in Europe.

(280.) Violent gales of wind, amounting to what may be called hurricanes, occur pretty generally everywhere except on the equatorial seas; but in the Steppes, in the interior of Asia, and in the Siberian plains, at the foot of the Altai, as well as among those and the Tang-

nou mountains, as described by Mr. Atkinson, they appear to be singularly frequent and furious. The true hurricane, cyclone, or typhoon, however, is restricted to very special regions, and its production (as explained in METEOROLOGY) is the result of conditions requiring the ascent of locally-heated columns of air or vapour, with a free in-draft from all sides. Accordingly they are limited at sea to those situations where (under the necessary conditions as to latitude) currents of heated water exist. Where (as in the Gulf Stream) the current is limited in breadth by a well-defined boundary, within which the water is very much warmer than the sea on either side, they follow, with what may well be called considerable precision, the general course of the current: describing parabolic curves in their progress, having the island of Bermuda for their focus. In the Indian and China seas they appear in the neighbourhood of the warm currents, but these currents being much more diffuse and ill-defined than in the case of the Gulf Stream, the region over which they prevail is correspondingly ill-defined; and in the China Sea this is still more markedly the case, though bearing a very obvious relation to the warm-water currents skirting the east coasts of Asia.

(281.) Earthquakes, of course, habitually infest countries adjacent to active volcanoes—such as Sicily and Calabria in Europe, and the neighbourhood of the Andes

in South America, where they are stated by Humboldt to be so frequent, that their occurrence, unless severe, is no more regarded than that of a shower in Europe. Java, Sumatra, Japan, and the islands of the Eastern Archipelago, are also exceedingly subject to such visitations. But, besides these, there are districts which, for geological regions less apparent, being out of the vicinity of any active volcanic vent, are infested with frequent earthquakes. They may, however, be for the most part traced for an origin to mountain chains in which either unequivocal evidence of long extinct, and therefore possibly still dormant, volcanic power, can be adduced, or which stand out as grand original axes of upheaval. Thus the whole of Upper India, and a large portion of Western India, from the Himalaya to the mouths of the Indus, is very liable to earthquakes, evidently referable to the Himalayan range as an axis of emanation, and proving clearly that the forces which originally upheaved those mountain masses, are still active, though their energy may perhaps be expended in maintaining them at their present elevation. Between 1800 and 1842, no less than 162 earthquakes have been recorded in these districts (K. Johnston). In 1843, 23 were observed, and since that time 4 or 5 annually. In the peninsula of India they seldom occur below 15° N. latitude.

(282.) Traceable to the neighbourhood of volcanoes not quite extinct, or which, within historic times, have

shewn signs of activity, we find Greece, Turkey, Asia Minor, Syria, and Palestine, with the district adjacent to Elbruz and the Caspian Sea and the Caucasus, noticeable as earthquake regions. Antioch was the centre of one of the most terrible and destructive earthquakes on record in A.D. 526, and Syria was visited no longer ago than 1837 with an earthquake extending over 4000 or 5000 square miles of country.

(283.) The south-eastern districts of North America along the ranges of the Appalachian and Alleghany Mountains, are liable to frequent earthquakes. More than a hundred have been noticed in the last two centuries (Keith Johnston), which, to judge from the direction habitually taken by their oscillatory motion (from S.E. to N.W.), would seem to owe their origin to some deep-seated centre of action beneath the line of the great Mexican volcanoes. By one of the more recent of these, the whole valley of the Lower Mississippi was violently agitated, and its levels permanently altered. Lastly, quite beyond all reference to any reasonably distant source of volcanic power, we find a district of very limited extent in the county of Perth, near Comrie, in Scotland, where a year seldom passes without a shock, though never severe enough to do any material damage.*

* In 1860 a shock of an earthquake was felt in several places in Kent, sufficiently powerful to set bells ringing and to throw down loose articles in dwelling houses.

In the Cape districts of South Africa, too, still more remote from any such centre of action, slight shocks are far from unfrequent. Generally speaking, what may be called the earthquake belt of Europe is conterminous, or nearly so, with the zone of newer igneous formation and extinct volcanoes, described in art. 127.

(284.) On the other hand, vast regions, chiefly extensive alluvial plains, or the low districts which extend out to great distances from the principal mountain chains, enjoy an immunity from earthquake shocks, as, for instance, America east of the Andes, and the great plains on the north-east of Europe, and the north of Asia. Where historical evidence is deficient, we have

Fig. [illegible]

often proof, from the continued upright position of ancient monuments, both natural and artificial, of the absence of at least any great earthquake since their erection, or since their attaining their present form, and

that, too, in situations where such complete exemption could hardly have been expected. Thus in Mexico, on the Mimbre River, near El Paso on the Rio Grande, we find described and figured by Bartlett (*Personal Narrative*, &c.), rocks, as in the annexed cut, which could not possibly have resisted even a very inconsiderable shock. On the west coast of Greenland (much of which is of volcanic origin) the same conclusion may be drawn from the existence of a remarkable slender pillar of rock 200 feet in height, figured by Dr. Kane under the name of Tennyson's Monument. An ancient column in the country bordering on the Indus, said to have been erected by Alexander the Great as the landmark of his Indian conquests, has been in like manner appealed to in favour of an exceptional degree of stability in its site in a region generally much subject to agitation. Pompey's Pillar affords similar evidence for Egypt during the last eighteen centuries, though its prostrate obelisks testify no less distinctly to earlier concussions. The Pierre Botte, in the isle of Mauritius, offers a similar testimony. From the immense weight and singularly slender support of the block on its summit (perched on a pillar of rock 1500 feet above the sea), it must have been precipitated by a very moderate shock given to its base.

Terrestrial Magnetism.

(285.) We shall here confine ourselves to a very general coup d'œil of this branch of terrestrial physics, and to the exposition of the chief outlines of those facts which regard the distribution of magnetism over the globe, and which are rather of a geographical than a physical nature, referring for a more detailed account of it to special treatises, and, *inter alia*, to the article on Magnetism in the Encyclopædia Britannica. In so doing we will suppose the reader to have before him a *chart of the world on the Mercator projection*, with two polar charts of the arctic and antarctic regions, or our chart in Plate I. in their stead.

(286.) The magnetic elements which observation furnishes are—1*st*, The horizontal direction of the needle, or its "declination" east or west from that of the astronomical meridian of the place of observation which may be regarded as + or −; the zero corresponding to the absence of any such deviation. 2*dly*, Its dip, or the "inclination" to the horizon, when suspended by its centre of gravity, and allowed freely to take its own position. When the north end of the needle points downwards, the inclination may be regarded as +, when it rests horizontal, as 0, and when it points upwards, as −. 3*dly*, The intensity of the horizontal component of the total directive power of

the earth on it; and *4thly*, That of the vertical component of the same total power. By the relation subsisting between these forces and the geometrical elements above mentioned, any three of them being given, the other may be found, and, moreover, the "total intensity," or the absolute directive power of the earth on the needle, from whose vertical and horizontal resolution the two forces originate. The *declination*, the *inclination*, and the *total intensity*, or simply *the intensity*, are the three primary features which the magnetist regards, whose amount and character in all regions of the globe magnetic charts are constructed to exhibit to the eye, on the same principle as the exhibition of the distribution of heat by a series of isothermic lines. If all the places in which each of these primary elements holds one and the same value be connected on a chart of the world by its appropriate curve, and if a series of such curves be laid down, in which that value is varied by successive steps of 5°, or 10° + and — from 0° for the angular elements, and by successive 10ths or 20ths of the maximum intensity, or of any arbitrary and convenient unit of directive force, we obtain charts respectively of the "Isogonal," "Isoclinal," and "Isodynamic" magnetic lines as they stand related to the configuration of the land and water of the globe, and to its meridians and parallels. The several elements themselves, it should be observed, are attainable by

observation, even at sea, with a precision truly marvellous, and little short of that attained by astronomical observation. General Sabine, who has bestowed infinite pains on the collation and discussion of all the recorded observations of voyagers, travellers, and those specially instituted in "Magnetic Surveys," has constructed such charts for the epoch of 1840, which form part of the Physical Atlas of Mr. Keith Johnston, from which, and from the introduction to vol. iii. of the Toronto Observations, the following particulars are mainly collected:—

(287.) The globe is divided into two magnetic hemispheres, a northern and southern, in the one of which the needle dips northwards, or the inclination is +, and in the other the reverse. The line dividing these is not *precisely a great circle of the globe, but does not deviate* very widely from one. It is not coincident, however, with the earth's true terrestrial equator, but inclined to it at an angle of 12°, having its nodes or points of intersection with it, the *ascending* in longitude 3° ±, and the *descending* in 187° ± east of Greenwich. Its principal deviation from a great circle consists in a rather abrupt abnormal excursion from its general course southwards, where it crosses the east coast of South America and runs into the Atlantic.

(288.) Along the whole of this "line of no dip," which is sometimes called the "magnetic equator," the

needle, of course, rests horizontally. Receding from it on either side, the dip increases gradually (and, on the whole, not very irregularly in low magnetic latitudes) from 0° up to 90°, which it attains at two points, and *two points only*, which are very commonly designated as the North and South Magnetic Poles. These points have been attained, the northern pretty accurately, the southern nearly, by Sir J. C. Ross in his memorable arctic and antarctic voyages of exploration. The former lies in lat. 70° N., long. 263° E.; the latter in lat. 75° S., long. 154° E. They are, therefore, not diametrically opposite to each other, nor either of them coincident with the geometrical pole of the magnetic equator; and hence arises a want of symmetry in the isoclinal curves, which, however, follow, with some approach to fidelity, a parallel course on both sides to the magnetic equator.

(289.) The globe is also divided into two ideal magnetic hemispheres, by a medial line, or equator of *minimum intensity*; and these hemispheres are, upon the whole, pretty nearly conterminous with those of north and south dip, the medial line being here also not very widely different from a great circle, 12° or 14° inclined to the true equator, and intersecting it in two points, 180° distant in longitude, viz., 32° $\pm$ and 212° $\pm$ east, for the ascending and descending nodes respectively. And it deserves remark, that in this also the chief abnormal deviation from the general course of the great

circle is of the same character, and occurs nearly at the same place, as in the other equator, about the middle of the Atlantic. The intensity is, however, not exactly equal in every part of this line, though always less in it than in any part of the adjacent region north or south of it. The point of absolutely least magnetic intensity on the globe is situate in the mid-Atlantic, somewhere about the parallel of the tropic of Capricorn, its exact position being, from the nature of the case, very difficult to define. The system of isodynamic lines is more complex than that of the isoclinal, and the simplest conception which can be formed of them is, to regard them as the level lines of an ideal model surface, of which the elevations above the sea-level are proportional in every place to the intensity at that place. So defined, this surface will have a channel or valley running round the whole course of the magnetic equator, from which it will ascend on either side, so as to form two great mountain-like protuberances, each occupying one hemisphere. The least magnetic intensity anywhere observed is 0.9 parts of an arbitrary scale, on which the greatest is 2.05, if we suppose the lowest point of the equatorial depression to be 900 feet above the sea-level, the highest culminating point of the whole surface will be 2050. This point is ascertained by the observations of Ross to be situated nearly on the antarctic circle, at about 130 long. E., in Adelie Island. Besides this, the course of the

level lines indicates the existence of a second culminating point or pole of maximum intensity, at a still higher southern latitude, and somewhere about the 240th degree of longitude, but which has not yet been approached near enough to define its exact situation. In the northern hemisphere are also two similar culminating points or maxima, the one in Siberia, rising to 1750, nearly at the point where the river Lena crosses the arctic circle, about the 120th degree of longitude, and the other to 1850 in North America, about 54° N. lat. and 270° E. long. south-west of Hudson's Bay. Between these culminations runs a line of depression, following nearly the course of the meridian, passing through Behring's Straits, and bisecting the Pacific on one side of the globe, and passing out of the Arctic Sea by Spitzbergen, and down the Atlantic on the other.

(290.) Lastly, the globe is again divided (though less definitely) into two magnetic hemispheres, or rather two very unequal compartments, an eastern and a western, by the *line of no declination.* This line (which necessarily passes through both the poles) appears on a Mercator's chart (in which the poles cannot be represented), as two distinct lines, which, were it a meridian, would be at right angles to the equator, and cross it at 180° difference of longitude. Such, however, is not the case; neglecting sinuosities, it assumes the aspect of two oblique lines running from N.W. to S.E., at angles of

about 70° with the equator, and dividing it into two unequal arcs of longitude at the 100th and 310th degrees east: in the Indian Ocean, southwest of Sumatra; and at the mouth of the Amazon river. Of the compartments so defined, the smaller, which may be termed the western, inasmuch as in every part of it the needle deviates westward from the meridian, includes the north-eastern corners of both North and South America, the whole of the Atlantic, all Europe and Africa, nearly the whole Indian Ocean, and the west of Australia. The other includes, with one exception, all the rest of the world; but that exception is a very remarkable one. Insulated in the midst of its north-western portion, occurs an oval space of an elliptic form, its longer axis following the meridian of 133° E. and its shorter the parallel of 50° N., extending over a large portion of Eastern Siberia (including Yakutsk), half the sea of Ochotsk, the Sea and Isles of Japan, the Yellow Sea, and the North of China, within which the declination is westerly, and in its central portions exceeds 6° W. This oval is part and parcel of a medial belt of relatively smaller easterly declination which may be traced along the whole course of the easterly compartment, and which leads directly across that small equatorial oval of relative cold spoken of in art. 255, the line of junction holding a similar inclination to the equator, and pointing, with the other features of this system, strongly to an analogy

between it and the system of lines marking out the regions of relative warmth and cold there described.

(291.) In middle latitudes of the northern hemisphere, when the sun is *east of the meridian* during the *forenoon*, the needle points more eastward than on the average of the twenty-four hours; when west *also* during the afternoon, more to the westward. These movements are reversed at stations in the southern hemisphere. The fluctuation so arising is called the solar diurnal variation and its average over the year the *mean solar* diurnal variation. There exists, then, a line which may be regarded as a magnetic equator of a third kind, in which the *mean solar diurnal variation* is *nil*. This line is supposed to be not very different from the line of *minimum intensity*. But in addition to these diurnal periodicities, there is an annual one depending on the sun's declination. When the sun is north of the equator, the diurnal variation, as above described, at stations north of the magnetic equator is exaggerated, at southern ones palliated, and *vice versâ;* and in consequence of this it happens, that at stations on this third magnetic equator, although the *mean* diurnal variation on an average of the whole year is *nil*, yet, during one-half of the year a diurnal variation, having a northerly character, exists, and during the other half a southerly.

(292.) Besides these regular fluctuations of magnetic action, others of a very singular character exist, to which

the name of "Magnetic Storms," or "irregular disturbances" of the three elements, has been given. They are in the nature of sudden and extensive deviations of the needle from its normal position and force. They occur quite unexpectedly (subject to a condition presently to be mentioned) and simultaneously over very extensive regions, and even, in some instances, over the whole earth; so simultaneously, indeed, that differences of longitude may, in particular instances, be ascertained by their means. Their cause is unknown, but is presumed to be connected with electric discharges, restoring the equilibrium of electric tension, somehow disturbed. Utterly irregular as these magnetic shocks are as to their particular moments of occurrence, and as to their degree of intensity, they yet, taken in their totality, and on a great average, obey the law of solar diurnal periodicity, but with the singular peculiarity of having, at each station, epochal hours peculiar to that station, and not identical with the regular epochal hours.

(293.) By far the most remarkable feature in the magnetic system of the globe, as expressed by their several systems of allineation, is its state of secular change, by which all the isogonal lines are sweeping *westward* in the northern hemisphere, and *eastward* in the southern. From this it happens, as a necessary consequence, that *their forms* are in a constant state of change, and from this, too, we may learn to receive with

much suspicion any general theories as to the dependence of directions of mountain chains and mineral veins, on the direction of the magnetic forces in action, seeing that if the present rate of variation should continue, or have continued uniform for a few centuries (to say nothing of great geological periods), the magnetic state of the globe must have been in former ages, and will be in future ones, quite different from the present.

(294.) It appears to be placed beyond a doubt that the moon acts *directly* as a magnet on the earth's magnetism, producing periodical fluctuations in the latter of extremely small amount, and which belong rather to the department of Cosmical Physics than to that with which we are here concerned.

Distribution of Mineral Products.

(295.) The number of chemical elements which go to constitute the total mass of our planet, so far as at present known, amounts to about 60, and every year is adding to their number, and to that of the already innumerable compounds which they form with each other. They are distributed, however, in such extremely unequal proportions throughout nature, and there are so many of them which, so far as we at present see, play quite a subordinate part in the general economy of the world and in useful applications, that when we

come to confine our regards to those of primary importance, we find the list much narrowed.

(296.) The elementary substances which occur among the materials of the accessible crust of the globe in such abundance as to constitute appretiable aliquot parts of its total amount, are—I. *Gaseous.* (1.) Oxygen.—This constitutes one-fifth of the atmosphere, eight-ninths of the sea, half the siliceous and calcareous, and more than half the aluminous rocks and soils, besides entering as a large element into almost every other mineral substance, so that it cannot be reckoned as constituting less than half the ponderable matter of the globe. (2.) Hydrogen: which forms one-ninth of the ocean, and of all that water which enters into the essential composition of a great many minerals, and the whole hygrometric contents of the atmosphere and of the soil. It enters also largely into the composition of coal, combined with carbon. (3.) Chlorine, as an element of sea salt, and, with this exception, occurring only very sparingly. (4.) Nitrogen, constituting four-fifths of the atmosphere, and otherwise very sparingly disseminated, existing chiefly as a constituent of the nitrates of potash, soda, and lime, which occur in some abundance, disseminated through the soil in India, Persia, and the deserts of Arabia and Africa, efflorescing in caves in America. The nitrate of soda forms strata of considerable thickness in Peru and Chili, on the western slope of the Andes.

(297.) II. *Solid.* The oxides of silicon, aluminium, and calcium, with that of carbon in the state of carbonic acid in the limestones, and of iron as an ingredient of almost universal intrusion into every other substance, constitute an overwhelming majority of the solid materials of the earth. After these probably may be placed those of potassium and sodium in the state of alkalis, forming a very notable portion of the granitic masses (as felspar and albite), and entering into the composition of a great many other bodies, especially (soda at least) into rock salt and sea water. Magnesia, too, as a characteristic element of the rocks of the serpentine character, and entering very influentially into dolomite and into many limestones, is entitled to rank among the more prominent ingredients of the land, though the sea is the source from which, exclusively, it is procured for human use. Carbon occurs as a primary and principal ingredient only in the anthracite and coal formations. The other chemical elements occur only occasionally and locally in any abundance, in veins, mines, and quarries, or disseminated in crystals and nodules in rocks, or as subordinate elements of composition in some or other of the more abundant rocks, or scattered through nature by their disintegration and dispersion.

(298.) The crystalline rocks have no doubt been the origin from which (ultimately) the stratified ones have been derived. From their destruction, partly mechani-

cal, partly chemical, have been produced, by water-washing and graduated subsidence, siliceous and argillaceous strata—the former essentially consisting of the *quartz and other* hard and unattackable crystalline ingredients, which the action of the waves has been able only coarsely to pulverize, and which have, therefore, been deposited near the shore; the latter, of the aluminous portion chiefly set free, in a chemically divided or flocculent state, by the decomposition of the other ingredients, such as felspar, and of the infinitesimally thin and filmy micaceous scales set loose and floated away to remoter places of quiet deposit. Thus have originated the two great families of the secondary and tertiary rocks; the siliceous and argillaceous, however, hardened and recompacted by subterranean heat and pressure. The third, or calcareous and cretaceous family, it can hardly be doubted, have arisen—1st, From the labours of the animalcule and molusc; 2dly, From the submarine effusion of calcareous springs (Lyell); and 3dly, From the degradation of calcareous mountain masses, themselves the successors and representatives of former ones, but which have yet, in all probability, undergone the solvent action of sea-water, preparatory to their re-aggregation by the agency of organic chemistry.

(299.) We may consider the mineral products of the earth, in relation to human use, under the general heads of materials for our structures, for our tools and utensils,

for objects of ornament and luxury, and for medical use, and domestic and manufacturing consumption. The first of these divisions need not detain us long. Wherever rocky masses occur capable of being quarried and shaped into blocks of sufficient coherence to resist the weather (and there are few strata which, in some part or other of their extent, do not furnish such), building materials are not wanting. For vast and massive structures intended for indefinite duration, and in which delicacy of finish is of less importance than resistance to weather or to violence, granite is admirably adapted; not, however, all equally so. Such granites as contain potash-felspar in great abundance are attacked and corroded by the carbonic acid of the air, assisted by rain and frost. The syenitic granites, or porphyries (of which, as examples, the Egyptian obelisks consist), and those granites in which felspar is replaced by albite (soda-felspar) are far less liable to such disintegration. That of the Aberdeen quarries, of which most of the great granite structures of London consist, is of this description. As a material for the greatest structures, granite presents the advantage that masses of any magnitude can be procured of perfect continuity. These are detached from their beds by primitive but very ingenious contrivances, which must have been known and practised from the earliest times. In some cases grooves are chiselled in the rocky mass, and holes cut at

brief intervals along them, into which wedges of baked wood are driven. These, when moistened, swell, and by their simultaneous expansion determine a fissure along the direction of the groove. In erecting an obelisk at Seringapatam, a block 70 feet long was separated from its bed by native workmen, by cutting a deep groove, along which was maintained a line of fires. When the rock had become sufficiently heated, water was poured along, the fires extinguished, and a crack determined along the groove.

(300.) Few but the vastest and most important structures are of granite. Its hardness, and the expense of working it to a smooth surface, prevent its general use as a building material. It is chiefly among the calcareous rocks, the marbles, the oolites, the nummulite limestones, and the harder portions of the chalk formation, as also among the close-grained sandstones, which admit of being easily quarried and sawed into shape, that the architect finds his best resource. Many of the grandest monuments in ancient Rome are constructed of the Travertine, a calcareous deposit from the numerous carbonated sources which occur in abundance along the base of the Apennines, at Volterra in Tuscany, at Terni, and over great districts in the immediate neighbourhood of Rome, and which is seen in process of formation to the present day, by the concretion of mosses, and other small aquatic vegetation percolated

by water saturated with super-carbonate of lime. Marbles, adapted for architectural purposes, are of pretty common occurrence, but those fitted for the sculptor's use are exceedingly rare. The finest are those which have furnished, from the quarries of Pentelicus, near Athens, the material of the Parthenon, and those of Mount Marpesus in the Isle of Paros, whence have been derived those masses on which the genius of the Greek sculptors has stamped the impress of immortality, and which in the Arundel marbles, yet preserve the recorded chronology of that wonderful nation. The finer grain and snowy purity of the marble from the quarries of Carrara, on the Gulf of Genoa, make it even still more prized. An excellent marble for the more costly architectural purposes, though less so for sculpture (being deficient in whiteness), is obtained in abundance from the Pic de Gerx, in the French Pyrenees.

(301.) The wide dissemination of the calcareous formations is of the last importance in an architectural point of view, from their furnishing the chief and most indispensable material of cement. Where lime is wanting, oyster and other sea-shells near the sea-coast may offer an excellent substitute; but its absence in the interior of a continent is an evil of no small magnitude. Much of the Cape Colony is seriously inconvenienced by it. As a chemical agent, too, and as an agricultural application, it is of immense importance, though when

magnesia occurs as an ingredient in limestone, it acts as a poison on vegetation; and large tracts of country in which this is the case, in the interior of France, in the north of England, in the neighbourhood of Naples, and elsewhere, are doomed to hopeless sterility from this cause.

(302.) Among the argillaceous rocks, the slaty ones claim attention, by reason of their fissile structure and great resistance to weathering, which renders them peculiarly adapted to roofing, and to a variety of other purposes. It is very remarkable that the "slaty cleavage" is never coincident with, but always highly inclined to, the planes of stratification. This Messrs. Tyndall and Sorby have explained, we think, to a certain extent satisfactorily, by referring it to the effect of lateral pressure determining the parallel direction among innumerable disseminated infinitesimal films of mica; but they have not shewn how such pressure originated, or why it is always lateral. Perhaps we may be pardoned for interrupting the matter immediately in hand by a few words on this point. It is well known to geologists that the slaty rocks are subject to very singular and extravagant contortions, the layers being often folded and refolded on each other like crumpled folds of linen. This is generally ascribed to the effect of violent intrusion of other rocks by the action of upheaving forces, acting on matter softened by heat, or only partially consolidated. A less violent origin of the phenomenon seems to us

not improbable. The aluminous strata have probably been deposited in a much more minute state of subdivision, and of a more slimy consistency than the siliceous. Suppose such a deposit to take place uniformly over the whole of an ocean basin, with sides inclining generally inwards, and having irregularities in them, till the irregularities are filled in, and the bottom reduced to a, generally speaking, basin-like concavity. Up to a certain point, the friction of the bed will retain the deposited matter on the slope, and in this way strata nearly uniform and parallel will be formed. But as the thickness of the whole increases, the weight will overcome the friction, and the still soft strata will yield inwards on all sides towards the central portion of the basin, increasing the thickness there, and at the same time crumpling the strata into contortions where they slide over the irregularities, and congregate towards local centres of depression, while yet the middle thickness increases; and that of each stratum individually (if the process go on slowly and tranquilly), by a general lateral compression and vertical dilatation of the whole central mass (however crumpled) does so also: which is all that the compression theory requires to account for the existence and direction of the cleavage in question. It seems by no means impossible, indeed, that instead of requiring the motive power of the volcano and the earthquake to wrinkle and contort the strata in the manner

observed, such wrinklings and contortions (or rather the slippages to which they are here attributed, when sudden), may, by displacing the incidence of pressure on the ocean bed, be themselves causes to which some at *least of those phenomena* may be owing.

(303.) The finest slate quarries in Britain, and probably in the world, are those of Penrhyn in North Wales. Between two and three thousand workmen are there constantly employed in quarrying and cleaving the slates, which are conveyed to every part of Britain and of the world, for roofing and writing slates and slabs.

(304.) Among the crystalline schists of the metamorphic series, it is no uncommon thing to find portions, especially of the mica slate, which allow large and tolerably even slabs to be detached, which in Alpine countries are used largely in buildings of the common kind. Many basalts and lavas afford excellent material, but their dark colour gives the piles constructed from them a sombre and heavy aspect. The cathedrals of Clermont and Le Puy afford examples of this.

(305.) Gypsum (sulphate of lime) enters as an ingredient in cements, casts, and stuccos, and is largely used wherever moulded forms are required and great hardness is not essential. In its natural *habitat* it is an almost universal concomitant of rock salt and salt springs, though in some (as at Cardona in Spain) it is absent, and in others (as at Bex, near Vevay) it occurs

anhydrous, and therefore useless for such purposes. Large beds of it, however, occur in the secondary and tertiary formations (seldom or never in the lower series) without the accompaniment of salt, as in the older tertiary basin of Paris (whence its ordinary name of plaster of Paris), in many parts of Switzerland, in North Italy (as at the head of the Lake of Garda), and in the sub-Apennine marls of the older Pleiocene, in Sicily, near Girgente, where it outcrops in crystals of very singular structure.

(306.) The mineral products which contribute to the construction of our tools and utensils are almost entirely either the metals, or those which go to the formation of earthenware and glass. Among the useful metals, *iron* holds the first rank. Owing to its high attraction for oxygen it is seldom found native (though instances do occur, as at Steinbach, Eibestock, at Kamsdorf in Saxony, and in Mont d'Oule, near Grenoble, in France), unless in masses to which a meteoric origin is usually assigned, and which occur detached and insulated in various places. The principal masses are—the great Siberian one described by Pallas, containing chrysolites; that of Otumpa, 70 leagues east of Santiago, "in the vast plains of the Gran Chaco, where, as in the Pampas of Buenos Ayres, *not a stone is to be seen*," which was brought to England by Sir Woodbine Parish, and now in the British Museum, and which weighs 14 cwt.;

that of Elbogen, in Bohemia; and that of Hraschina, near Agram, in Croatia (which was seen to fall). Many masses are scattered over Louisiana, and others have been discovered in the Esquimaux country and on the Senegal river. The great mass of Otumpa is far from solitary, however, in that region, and the masses which there occur are described "as huge trunks with deep roots, supposed to communicate with each other." Though alloyed with nickel (a character common to all these so-called meteoric masses) this circumstance, and their abundance near Santiago, "induced" Sir W. Parish, "as well as others in S. America, to hesitate in adopting the meteoric theory," a hesitation greatly increased by the existence in some sandy plains near Toconao, ten leagues from San Pedro, in the province of Atacama, in Peru, of an extraordinary quantity; where, besides detached masses, a vein of solid iron of the same kind *is asserted by the natives to exist.* This suspicion of other than a meteoric origin of these masses is considerably increased by the occurrence of a similar fact *in South Africa.* "*'Eight days' journey east of Bethany* missionary station, 'meteoric iron' is found in apparently inexhaustible quantities." Anderssen, to whom we owe the account of this fact, had "seen lumps of several cwts. brought thence, so pure and malleable that the natives convert it into balls for their guns, without any previous application of fire."—*Lake 'Ngami*, 2d ed., p. 325.

(307.) Iron, however, happily for man, mineralized either by sulphur or by oxygen (in which latter state of combination only it is available for smelting), is diffused over all the world in immense abundance. In the island of Elba are whole mountains consisting of the specular oxide. The mountains of Taberg in Lapland, and Pumachanche in Chili, consist almost entirely of magnetic iron ore, and mountains of it occur in the Minas Geraes in Brazil, where in one place it forms a mountain (Itabira) of the pure oxide, 5250 feet high. It is also plentiful in Corsica, Savoy, Bohemia, Saxony, Russia, and the East Indies. In Britain the principal iron mines fortunately accompany the coal fields, as around Birmingham, in Staffordshire, and in the great coal-basins near Pontypool, Merthyr Tydvil, and Glasgow. The same coincidence happens in Belgium, and in the coal district near the St. Etienne, in France. It is chiefly the red and argillaceous iron ores which are so associated. These, though mostly occurring in secondary and alluvial countries, are also, though more rarely, found in the so-called primary formations. On the other hand, the oxydulated and brown iron ores belong mainly, though not exclusively, to these formations.

(308.) Among the other metals, it may be observed generally that manganese, like iron, is found among the oldest rocks. Tin, molybdæna, tungsten, titanium, cerium, uranium, chrome, and bismuth, are found almost

exclusively in such veins as traverse the lower crystalline rocks. Arsenic, cobalt, silver, nickel, and copper, in these and in the higher members of the same series. Gold, tellurium, and antimony, in the upper crystalline metamorphic, and in the older secondary or silurian rocks. Lead, zinc, and mercury are found in greatest quantity in secondary formations. Platina, with its associated metals (the platinoid group), has, with one exception, not hitherto been found in the matrix *in situ*, but (as is also largely the case with gold) dispersed in alluvial gravels, sands, and clays.

(309.) Many of the metals are found almost exclusively in veins. These are fissures or cracks in the rocks, usually of no great breadth, which are filled—whether by injection from below, by sublimation, by infiltration from above, or by crystalline segregation determined by voltaic currents resulting from chemical reactions,—with materials of quite a different nature from the rocks in which the fissures occur. The contents of a vein are usually highly crystallized, and arranged with a certain symmetrical reference to the boundary surfaces, so as to form corresponding layers on either face of several different spars (especially fluor), with the metallic deposit, whether sulphuret, oxide, or in union with acids, occupying the middle; such at least is the normal arrangement of the contents of a mineral vein, though it is often widely departed from.

Wherever a mineral vein traverses stratified rock, or differently characterized beds of an unstratified one, the strata on its two faces are very frequently, indeed almost generally, found not to correspond—one or other side of the mass having shifted in level (whether by upheaval or subsidence), forming what are called *faults* in the strata. When the fissure has been accompanied with and perhaps formed by the violent injection of non-metallic liquid matter, the vein is called a dyke, whether of granite, basalt, or other igneous rock. In such a case the dislocation is a natural concomitant of the violence used in the formation of the dyke; but it would seem probable that metalliferous veins have, at least in many instances, subsequently and quietly filled up empty intervals, themselves the results of previous violent displacement, not accompanied with the injection of melted matter.

(310.) Veins, as well as dykes, are evidently of different ages, and belong to different and successive actions of the dislocating forces. In Cornwall, where the principal tin mines in Britain, and perhaps in the world, are situated, the stanniferous veins run almost universally east and west, while those which intersect and upheave them, producing or accompanying dislocations and faults in them (which this fact proves to be posterior in date), cut them at various angles, and those which run north and south are rarely metalliferous.

The same tendency to an east and west direction in metalliferous veins generally has been remarked in other mining districts, and has been (perhaps rather hastily) drawn into a general law, and referred to a generally westerly course of voltaic currents, connected, as is assumed, with the general meridional direction of the magnetic needle.

Copper, Tin, Lead.

(311.) Of the metals found in veins, these are the most abundant and most generally useful, either pure or in mixture. Copper occurs in granite in the slate formations, in the sandstones of the "Trias" (a connected system of three members—Keuper, Muschelkalk, and Bunter Sandstein—common in Germany), in certain porphyries, and in serpentine. The copper mines of Tunaberg in Sweden are in secondary limestone. In Cornwall, where, in the granite, a copper vein intersects a tin one, the former always disturbs the latter—a proof of later origin. Mines of copper are largely wrought in England, Germany, Sweden, and Siberia; less so in Spain, France, Ireland, Norway, and Hungary. Native copper is of common occurrence, and in North America, in the neighbourhood of Lake Superior, about its upper end, is found in blocks of several hundred tons in weight, so pure as to require to be cut with the cold chisel. Mala-

chite, or the carbonate of copper, which is valued almost as a gem when in fine specimens, is largely procured in the Siberian mines of the Ural and Altai mountains, and in the copper mines of Burra-Burra in Australia.

(312.) Tin has been generally considered to occur native in Cornwall; but, according to Phillips (*Mineralogy*, lxx.), the specimens which have given rise to this opinion have been found on the sites of old smelting works. Mohs (*Mineralogy*) does not admit it into his Order ix. of *native* metals. Its ores (always either oxide or sulphuret) belong exclusively to primitive countries, and the localities of its occurrence are comparatively few, viz., Cornwall, Saxony, and Bohemia, in Europe, Tenasserim, in the Malayan Peninsula, and Banca Island in the Straits of Malacca. Some stream works, in which the oxide is found, exist in Mexico and Chili. At Chesterfield, in North America, it has also been found.

(313.) Lead occurs very rarely in a native state. Its chief ore is the sulphuret, which is very abundant in most European countries—comparatively rare in Asia. In England, perhaps the greatest known depository of this ore, it occurs in the secondary limestones of Derby, Durham, and Northumberland, in clay slate in Cornwall and Devon. In Scotland, in the Lead Hills in Lanark and in Dumfries. In North America, in Massachusetts, it occurs in granite and other crystalline or metamorphic rocks, which is also the case in France and Spain.

Gold, Silver, Platina.

(314.) Gold and silver, though they derive their high estimation mainly from their application to utensils and ornaments of luxury and spendour, yet perform most eminently the offices of *useful* metals, as the materials of the most universal of all *tools* —coined money. Gold, owing, no doubt, to its low affinities for oxygen and sulphur, is exclusively found pure, or in alloy or mixture; all the alloys of a definite character, however, are very rare. In its *habitat* it occurs disseminated in nodules or threads in many rocks, but chiefly in quartz, and in the beds of rivers and alluvial deposits, the result of the degradation of such rocks. The long inhabited countries have been picked clean of their alluvial gold, but in newly-occupied ones it is still abundant; confined, however, to the palæozoic rocks in the neighbourhood of porphyritic eruptions, and to the districts adjacent to such rocks, with an *especial preference* for those mountain chains which run north and south. Such are the Mexican and Peruvian Andes, the mountain ranges of California and North-Western America (including the newly-discovered gold districts on the Fraser River and Vancouver's Island)—such are also the mountains on the east coast of Australia, to which the gold districts of Sydney, Melbourne, and Adelaide, owe their wealth. Such, too, is the Ural

chain, the chief source of the Russian gold. Gold also is found in Brazil, where almost all the rivers bring it down—in mines at Matto Grosso, and in Minas Geraes—in the Altai Mountains—in Hungary and Transylvania—in Japan, Borneo, and in the province of Yunan in China, as well as at the base of the Kong Mountain, and in very extensive regions in the interior of Africa, where gold dust is obtained by washing, and where the closer exploration of its mountain chains will no doubt lead to the discovery of rich deposits. The largest mass of native gold yet discovered is that recently found at Ballarat, weighing 2217 ounces, greatly exceeding that of Miask in the South Ural (36 kilogrammes = 1158 ounces) found at Zarevo Alexandrofski in 1842.

(315.) SILVER occurs in such immense abundance in Mexico and Peru, among the Cordilleras of the Andes, that it is hardly worth while to enumerate the localities of its feebler exhibition, such as Hungary and Transylvania, the Ural and Altai mountains, Armenia, Anatolia, Thibet, China, Cochin-China, and Japan. The most productive region of the Andes in silver is about Copiapo in Chili. In Peru, from Caxamarca along the whole range of the Andes to the desert of Atacama, it is very abundant. The most ancient mines are those of the "Knot of Pasco." At Potosi and at Chota the ore lies close to the surface. In the mines of Huantajaya a mass of pure silver weighing 800 lbs. has been found. Silver

is a very general concomitant of lead, and a large quantity is extracted from that metal. This used to be done by cupellation, the lead being burned off and again recovered; but is now performed by the neater and far less wasteful and costly process of crystallization, by melting the lead, allowing it to cool and crystallize, and pouring off the last portions from the crystals formed, which portions contain all the silver much concentrated.

(316.) PLATINA is a rare but extremely useful metal. But for utensils formed of it, chemistry could not have attained its present state of improvement, either as a practical art or as a science. It is found in very few localities—in Brazil, at Matto Grosso, in Choco, New Granada, St. Domingo, and the Ural Mountains, and almost always in alluvium.* According to the remark of Humboldt, the principal deposits of gold occur on the eastern, and of platina on the western side of the Ural chain. One of the most singular characters of this region is the frequent occurrence of the fossil bones of extinct pachyderms among the metalliferous sands. The largest "*pepite*" (nugget, *i.e.* ingot) of platina hitherto discovered is one of 25 oz. 1 dr., found in the gold mines of Condoto Choco, S. A. (*Phillips*).

(317.) Platina is *invariably* found associated with

* M. Boussigny found it in a syenitic rock associated with gold at Antioquia, in South America.

several other metals forming a family apart (the platinoids), of very singular chemical habitudes—viz., palladium, rhodium, iridium, osmium, ruthenium [and we think we have some reason to believe one, if not two more, to which if verified we should appropriate the names Astræum and Hebeum]. Of these, palladium also occurs alloyed with gold and silver in Brazil. Iridium, or rather its osmiuret, occurs in almost all gold in a state of *mixture, not of alloy*, and is deposited by subsidence, by reason of its *much higher specific gravity*, at the bottom of the crucible whenever gold, fresh from the mines or diggings, is melted in large quantities. It sometimes settles *in the finest dust* from the melted gold.

Zinc, Antimony, Bismuth.

(318.) Zinc is useful as an alloy tending to harden other metals, a quality which, in union with copper (producing brass, or bronze), is of the highest importance in many of its applications, and in earlier ages enabled it, with the admixture of tin, to supply the place of iron, then unknown or unworkable. [It is also of immense importance as a chief element in the production of voltaic electricity, for which purpose large quantities are consumed. Not, however, *destroyed*, for the metal can be recovered and used again; while in the process of its recovery (from the sulphate), Oxygen gas is disen-

gaged and may be obtained separate at a cost so moderate as to promise an abundant commercial supply of this invaluable element.* Its oxide, also, with silex, forms a beautiful glass.] ZINC is chiefly found in the state of sulphuret or carbonate, sometimes in veins of tin or copper, as in Cornwall, but most frequently associated with lead in the lead-mines of Derbyshire, in the Mendip Hills; in Scotland, in those of Wanloch-head; in Wales, in Flintshire. It occurs also in the mines of Freyberg, in Saxony, Bleiberg, in Carinthia, Tarnowitz, in Silesia, and Medziana Goro, in Poland. Enormous masses of pure calamine are found in some of the North American mines—in New Jersey, and other parts. It is also found in the Siberian mines. Indeed, wherever lead occurs, zinc may be expected.

(319.) ANTIMONY, which, besides its utility in hardening alloys, is also an important medicine, occurs in veins traversing gneiss at Allemont in Dauphiné. In Cornwall, in veins traversing those of copper and tin, at Andreasberg, in the Hartz—in Saxony, Bohemia, Hungary, Transylvania, Tuscany, in Mexico, and in Connecticut in North America. The chief deposits of BISMUTH (which is chiefly used as an alloy, as is also the case with Nickel), occur in the veins of primitive mountains. The chief localities are in the Cornish

* [In which case the revival of its use as a direct medical agent may be anticipated, besides many other most important applications in the arts.]

mines, Johan-Georgenstadt and Schneeberg in Saxony, Joachimsthal in Bohemia, in Transylvania, Swabia, France, Norway, and in Connecticut, N. A.

(320.) NICKEL exists in considerable abundance in China and Japan, whence it reaches us in alloy with copper as tutenag; also in veins of primitive rocks in Saxony, Bohemia, the Banat, and in France; in rocks of the metamorphic and transition series in the Hartz. It occurs also in Swabia, at Saltzburg, in Spain; in veins traversing serpentine in Silesia, and in copper-mines in Frederick County, and at Chatham in Connecticut, N. A.; in Cornwall, and in Scotland. It is an essential ingredient in the so-called meteoric iron, which it effectually preserves from rust.*

(321.) MERCURY occurs in few localities, the chief of which are the mines of Idria in Carniola, and Almaden in Spain, and it is prominent among the recent great metalliferous discoveries in California, where mines of it exist so extensive as to have given a new impulse to the working of the Mexican silver-mines, where its chief consumption takes place in the process of amalgamation. In medicine its valuable properties have been long recognized, and it has now taken its place among the

* Why should it not be introduced intentionally into the finer kinds of steel or into Bessemer's homogeneous iron, in the process of its manufacture, for that purpose? (*Verb. sap.*)

essential materials of modern warfare, by reason of the detonating properties of one of its salts.

(322.) At the head of metals useful in the chemical arts, and in these only, stands MANGANESE, whose ores are very widely disseminated both in the primary and secondary rocks, where it occurs in veins, beds, or irregular masses, in the state of black oxide, in which alone it is of any utility. It is found, too, in Cornwall, at Upton Pyne and Tavistock in Devonshire, at Bristol, near Aberdeen in Scotland, at Howth near Dublin, in Ilefeld in the Hartz, in Nassau, at Christiansand in Norway, at Platten in Bohemia, at Johann-Georgenstadt in Saxony, and in several places in Hungary, Moravia, Silesia, and France.

(323.) ARSENIC is of almost universal occurrence in combination with the other metals, forming arseniurets and arseniates. CHROME, first discovered in Siberia in combination with lead, is now almost wholly obtained from the chromate of iron, which occurs in copious abundance in Unst, one of the Shetland Isles. These, with Cobalt* (which generally accompanies nickel), al-

* [The quite recent discovery of the exceeding tenacity of metallic Cobalt, *which is double that of iron*, promises to place this metal in the first rank of mechanical utility. Oxygen being cheaply obtainable, its ores will in all probability be smelted, and the metal produced in large quantities; and should a cobalt-steel exist bearing similar relation in its qualities to those which ordinary steel bears to iron, there seems no limit to the improvement of our tools, engines, and every fabric in which lightness and strength have to be combined.]

most exhaust the list of metals useful in the manufacture of utensils, and in the chemical and medicinal arts.

OBJECTS OF CONVENTIONAL VALUE.—GEMS.

(324.) At the head of gems stands the DIAMOND, which, from its hardness, may also be reckoned among the useful materials as a tool. As is well known to chemists, it consists of pure carbon. It is found all but exclusively in alluvial detritus, and has never but in two or three instances been found forming an integrant part of any rock. As such, it was once observed to occur in scorodite, in a cavity of brown ironstone at Antonio Pereira, in Brazil, accompanied by micaceous iron, between Villa Rica and Sabara. Humboldt, or one of his companions in travel, detected it in the Ural, *in situ.* M. Harting (*Verh. der K. Akad der Wetensch.* Amsterdam. Deel vi. 1854) describes a diamond from Bahia, including in its substance definitely-formed crystalline filaments of iron pyrites—a fact unique in its kind, and, taken in conjunction with the affinities of iron and carbon at high temperatures, likely to throw some light on the very obscure subject of the ultimate origin of this gem.

(325.) Diamonds are found only in few localities. The principal are between Golconda and Masulipatam, in the peninsula of India, in Visapore, near Panna in Bundelcund, in the vicinity of Ellore, at Mallivully in

the Mustapha-nagar Circar (in a peculiar fat white clay associated with ironstone), in the peninsula of Malacca, in Borneo, where the largest diamond known (367 carats =1130 grains) was found, in Brazil, in the district of Cerro do Frio, in the country north of Rio Janeiro: also on each side of the Sierra Espenhaço, and on the affluents of the San Francisco river. The chief work is at Mandanga, on the river Jigitonhonha, where diamonds are found in an alluvium of pebbles called cascalhao; at Goyaz, Matto Grosso, and St. Paul's. Diamonds are also found in the Ural, and especially in the rich mining district near Beresovsk.

(326.) The SAPPHIRE, ORIENTAL RUBY, and SPINELLE, are chiefly found in Ceylon, in the beds of streams; the finest in the Capellan Mountains near Sirian in Pegu. Sapphires also occur near Billin and Merowitz in Bohemia, in the sand of rivulets near Expailly in France, at Brendola in the Vicentine, and at St. Gothard, but not in such quantity or of such value as to make their search remunerative. The spinelle is not uncommon in Brazil, where also, in the Minas Geraes and at Villa Rica, the TOPAZ abounds. The finest EMERALDS are found in New Granada, in veins traversing a formation referable to the epoch of the greensand or lower chalk. They occur also in Upper Egypt, and in the valley of Tunca in Santa Fé, in granite. The BERYL occurs in the greatest purity and abundance at Nertschinsk in compact ferruginous

clay, in Persia in a vein traversing granite, and in a similar *gisement* near Limoges in France. It is also found in Peru, Brazil, Saxony, and Elba, at Cairn Gorm in Aberdeenshire, and in Wicklow, Ireland. To enumerate the *habitats* of the inferior gems would be almost equivalent to giving a catalogue of mineral districts. The GARNET, however, may be mentioned as especially belonging to, and found imbedded in, the mica slate and gneiss formations. CORUNDUM, which, though not a gem, possesses the hardness, and consists of the same materials as one (the sapphire), and is on that account of great utility (in its form of emery) is found most abundantly in India, at Singraula near Sahapur, in Ava, on the Malabar coast, in Smyrna and the isle of Naxos, in Italy and Spain, in Saxony in beds of steatite in a schistose rock, and in Gellivara in Lapland. The ZIRCON is most abundant in Ceylon, in the districts of Matura and Suffragam, and is found also at Kalinovskoi near Beresovsk and elsewhere in the Ural, and in the zircon-syenite rocks on the Aggers Elv in Norway. The CINNAMON STONE is peculiar to Ceylon.

SALT, COAL, SULPHUR.

(327.) ROCK SALT is commonly disposed in thick beds, either superficially as in Africa, or at very great depths, as in the Polish mines at Wielicska; sometimes

at great heights above the sea, as in the Cordilleras and in Savoy. The greatest deposit in England is near Northwich in Cheshire. In Spain, at Cardona, it forms a rugged precipice four or five hundred feet high, of such purity as to require only pounding to be fit for use. At Lahore in India a similar mass occurs. In Affghanistan a road is cut out of solid salt at the foot of cliffs of that mineral 100 feet high. The island of Ormuz, at the entrance of the Persian Gulf, is a rock of salt. It is almost always found associated with gypsum.

(327, *a*.) Borax, a salt of great utility in the chemical arts, is one of rare and sparing distribution. The greater part in use is the product of a lake in Thibet, where, under the name of tincal, it is dug out in impure masses from the edges and shallows of the lake, being associated with common salt in the water. It occurs also in the province of Potosi in Peru. The Boracic acid is found in hot springs near Sasso in Tuscany, and in Volcano, one of the Lipari islands, in great purity. Soda, in the state of carbonate, occurs in abundance in the natron lakes of Egypt, and in four Hungarian lakes, and as an efflorescence on the surface of the earth in various arid and desert countries. Nitre is found encrusting chalk, limestone, or calcareous tufa, also in limestone caverns in North America, and in immense abundance as an efflorescence on the surface of the soil in several districts of India, as well as in Spain, Italy,

and Hungary. The nitrate of soda, or "cubic nitre," as it is sometimes improperly called, forms a horizontal stratum many feet in thickness, and forty leagues in extent, in the district of Tarapaca in Peru, near the frontiers of Chili.

(328.) Porcelain Clay results from the decomposition of the felspar in granitic formations. Under the name of kaolin, it is quarried in China. It occurs also in great purity at Aue in Saxony, and at Meissen, in Austria near Passau, at Limoges and near Bayonne in France. The porcelain manufactories of Worcester are supplied from St. Austel in Cornwall, at the foot of the granite range. In the granite districts of Ireland it also occurs abundantly.

(329.) Coal.—Happily for mankind this most useful mineral is very abundantly distributed over the world, though limited in its occurrence to those regions where the limestones of the (thence called) carboniferous series and their associated beds crop out to the surface, or under-lie other superficial beds at accessible depths. Coal is generally deposited in "coal basins," or great concave depressions of the strata, partly owing, no doubt, to the general curve of the ocean beds in which the deposit was formed, but much more to their being broken up and dislocated by lateral upheavals, so that the parts no longer correspond—a circumstance extremely favourable to their working, since the great inclination which

the beds assume would otherwise carry them down beyond the reach of the miner, were it not that their broken edges are thus brought up again and made to out-crop on the surface.

(330.) The "coal measures," or strata in which the *beds of coal occur, usually alternating* with clay and sandstone, are almost absolutely restricted to that group of the great geological series which used to be termed the transition series—that is to say, to the formations between the metamorphic rocks and the secondary limestones, etc., and more particularly to the upper Palæozoic formations between the Devonian and Permian groups, and in these, to the interval between the old red sandstone, the mountain or coral limestone and millstone grit below, and the new red sandstone and magnesian limestone above. From this circumstance (their coral substratum), from the nature of the fossils they inclose, and from the form and distribution of the carboniferous districts, it is inferred that their depositions took place in comparatively shallow seas, receiving the vegetable spoils of densely-clothed islands abounding in plants of a tropical character, and in particular, with arborescent ferns, flags, reeds, and large trunks of succulent plants. Few animal remains, and scarcely a single shell or coral, are found in the coal measures, while the vegetable forms, sometimes most beautifully preserved (though more ordinarily completely obliterated), which they

contain, sufficiently prove their whole mass to consist of vegetable matter consolidated by heat (after undergoing a specific peatifying action by long submersion in water) under a pressure sufficient to retain the more volatile portions of their structure in combination with the carbon, forming bitumen and all the varieties of hydro-carbon, which, as is well known, the distillation of coal yields in abundance. Where the heat has been very violent, the coal is converted into anthracite, or "blind coal," "culm," or "Welsh coal," which is almost pure carbon; and in some instances, in the neighbourhood of trap-dykes, into true coke, evidently from the effect of heat under insufficient pressure.

(331.) The coal measures would seem to mark an epoch of great interest in the geological history of the world, from the circumstance that whereas their strata bear every mark of great disturbance and violent dislocation, those incumbent on them are for the most part horizontal or comparatively little inclined. Such, at least, is the case in the great coal series of England and the Netherlands, and such is the impression strongly left by the moderate inclination and slight disturbance of the sandstones immediately incumbent on the great coal-fields of North America.

(332.) Coal occurs in immense abundance in all those parts of England, Scotland, and Wales where the strata above specified crop out, especially—(1.) In

Northumberland and Durham, in a district the central point of which is somewhere about Jarrow at the mouth of the Tyne, in which it has been calculated that between five and six thousand millions of tons of *workable* coal exist (*Phillips citing Thomson*); (2.) In South Yorkshire, Nottingham, and Lancashire; (3.) In Staffordshire and Warwick, in a region having Ashby de la Zouche for its centre; (4.) In what may be called the western and south-western coal districts, comprising Anglesey, Flintshire, Shropshire, South Gloucester, Somerset, Monmouth, and Glamorgan; (5.) The Scotch coal-field occupying the great central lowland of Scotland; (6.) The Irish counties of Leinster, Tipperary, Munster, Connaught, and Tyrone. The larger portion of the whole area of Ireland, indeed, is occupied by the carboniferous formations.

(333.) On the continent of Europe coal occurs in Belgium in the district about Liège; in France in the neighbourhood of Vienne on the Rhone. The south of Europe is, generally speaking, destitute of coal. It has hitherto been found but very sparingly in Russia. It has, however, been lately discovered, though of inferior quality, at a depth of 360 feet, near Moscow. By far the greatest system of coal deposits known, however, is that of the United States of America. It is considered that the state of Pennsylvania consists, in about one-third of its area, of coal-fields belonging to the great Appalachian

system s, which extend altogether over upwards of 60,000 square miles. One of the seams in this formation, near Pittsburg, is worked through a large extent of its outcrop as an open quarry. The Illinois coal-field, which covers an area as large as England, in Illinois, Indiana, and Kentucky, consists of horizontal strata, and has numerous seams of excellent coal. Michigan, New Brunswick, Nova Scotia, and Vancouver's Island, all yield coal in abundance. It occurs at the height of 14,750 feet in the Peruvian Andes. [A great coal-field has been also ascertained to exist at St. Catharine's in Brazil, extending 140 leagues along the coast from Loguna in that province, almost to Monte Video, and 60 leagues inland from the Atlantic to St. Gabriel, and perhaps further. (*Journ. Soc. of Arts,* ix. 110.)]

(334.) Coal is also found in a vast number of other localities both in Asia and Australia, in Asia Minor (on the coast of the Black Sea, near Trebizond), in Borneo, Formosa, Tasmania, and New Zealand. In India, coal occurs on the Damoda river; also in Silhet and Cashar.

(335.) SULPHUR often accompanies salt and gypsum. It is produced in abundance, accompanying the latter mineral and sulphate of strontia (all three superbly crystallized) in the mines of Catolica in Sicily. The greater part of the sulphur of commerce is procured from "Solfataras" or volcanic half-extinguished vents where for "Fumaroles" and fissures in the soil, the

sulphur is sublimed. The *Solfatara*, emphatically so called, near Naples, supplies an immense quantity. There exist also great masses of sulphur, constituting almost mountains, such as the Sulphur Island of the Luchu Archipelago. Great quantities occur among the volcanoes of Iceland, of Java, and of the Andes. It is one of the most universal of volcanic products.

Distribution of Plants.

(336.) Climate and soil are the elements which determine the abstract possibility of existence of all terrestrial and fresh-water vegetable productions. Their actual distribution over the globe involves, however, another element, which greatly limits the area over which particular classes and families of plants are found to prevail. Thus, while some not only will grow and flourish, but are naturally found indigenous, almost indiscriminately, wherever the soil and climate are suitable, there are others which are found native only in very limited districts, or even restricted to particular spots, removed from which they perish, or refuse to produce seed. Thus, the Disa grandiflora is found exclusively on the summit of the Table Mountain at the Cape of Good Hope, and no one has succeeded in getting it to grow elsewhere. The Coco-de-Mer (Lodoicea Seychellarum) is found only in the Seychelles Islands, and

though it can be grown in Mauritius, can never be brought to produce fruit there. The Hymenophyllum Tunbridgense is found hardly anywhere but on the sand rocks of Tunbridge Wells. These, however, and such as these, are rare and exceptional cases, as are also those of plants usually of very low organization, which grow only under special, and even artificial conditions, as in the decaying hoof of a horse, or on the outside of *wine*-casks. They are, however, only the extreme exaggeration of a principle which may be considered as of universal application—that of the repartition of families, genera, and species, in districts or regions more or less extensive, in which only they are indigenously found in full development, though perfectly capable of flourishing and propagating elsewhere when artificially introduced. Indeed, it is found in many instances, that plants so introduced into a new soil and climate, not only rapidly adapt themselves to it, but flourish with singular exuberance of growth, as if their old and original *habitat* had become in some degree exhausted of their peculiar *pabulum*, and they were there in process of dying out. This has been singularly exemplified of late in the instance of the Anacharis alsinastrum, an American river weed, not remarkable for any great exuberance of growth in its native streams, but which, having been accidentally introduced into some English rivers, has spread into others, and is becoming a pest by filling and obstructing

their beds in a way before unheard of. The thistles of the Pampas, of gigantic growth and immense extent of distribution, are said to be of European origin.

(337.) As the mean temperature of the surface-soil and of the air change not only with the latitude, but with the height above the sea, the same limits of temperature which restrict the *habitat* of a plant to a definite zone of latitude, or to the interval between two isothermal lines, will also be marked out on mountains or highlands of sufficient altitude, whose lower parts are situated in an isotherm admitting of its growth, by *zones of elevation. In such cases, the plant will be found flourishing at the base and up the slope, and gradually* becoming more and more stunted, till it disappears altogether. Thus, on a lofty equatorial mountain, every form of vegetation, from that of the equatorial to the polar regions, may exist, if the soil and water supply be fitting; each form occupying its appropriate zone. Of those which prevail on the Andes, and over the plains and lower elevations of Equatorial America, Humboldt has given a condensed view in a chart, from which our Plate III is copied, and which exhibits well the principle in question; and a reference to which will spare us much verbal explanation. The powerful influence which the element of moisture, as well as heat, has in determining the extent and limit of these mountain zones, is strikingly exemplified on the Peak of Teneriffe.

where, at lower altitudes, the cloud-level determines a moist atmosphere, and where, at higher levels, the extreme of desiccation is gradually attained; here we find, according to the recent report of Mr. P. Smyth, that on descending from Alta Vista, where (at an altitude of 10,700 feet) only lichens are found, we come, at the upper limit of 9800 feet, first on the Retama (Cytisus nubigenus), which occupies the whole zone, down to 5700 feet, to the exclusion of every other plant; then quite suddenly occurs the Erica arboracea, to the exclusion of the Retama, and of all other plants, except the Adenocarpus Frankenoides, which latter extends from 5900 feet to 4200 feet, not, however, mixing in the upper portion of this, its zone, with the Retama, but occupying cinders, while the latter holds the rocky ground. The Erica descends to 1800 feet of altitude, but in the lower portion of its zone it encounters ferns from 5400 to 2300 feet, the Androscenum Webbianum (4900 to 1400), the laurel (5000 to 3500), and the vine (3700 to 2300). Three thousand feet is the lower limit of the perennial mountain cloud, which separates the under from the upper current of wind.

(338.) The decrease of temperature with increase of altitude, proceeding at an average rate of 1° Fahr. for about 350 feet of altitude, it will be easy to compute at what height above the sea, on a mountain slope, situate on a given isotherm, a plant, the mean temperature of

whose most appropriate *habitat* is known, may be expected to be found, if at all. It is not, however, the mean temperature of the whole year, so much as the law of its distribution over the several months, and especially the temperature attained in the summer months, which principally determines the most vigorous growth of a plant, and the limits of its *reproductive* existence. The latter limit will, of course, be defined by the impossibility of its flowering and ripening its seed. When a plant cannot flower, it must, of course, die out, even if artificially introduced. Now, it has been laid down by botanists, that a plant flowers when the sum of the mean diurnal temperatures (or rather, as maintained by M. Quetelet, on apparently better grounds, that of the squares of those mean temperatures), from the epoch of the first movement of the sap in the spring, attains a definite amount, differing for each species of plant, but invariable for the same, under all circumstances. Wherever, then, on the globe, the climate is such, whether from the lateness of the spring, or the coldness of summer, that the appropriate sum is not attained up to the cessation of the annual cycle of the plant's activity, it cannot flower, much less fructify.* This appropriate sum has hitherto been determined for

* [This admits of exception in cases where the flower buds are formed in the course of one summer and expanded in the succeeding one, having outstood the intervening winter. Thus, under these conditions, in the

very few plants. For the common lilac, it is 4264 square centigrade degrees (Quetelet, *Probab.* p. 164, Transl.) As the effect of each day's warmth progresses in a higher ratio than that of simple proportionality, it is easily seen that a short and hot summer may (as experience shews it does) far outweigh, in its influence on reproductive vitality, the rigour of a prolonged and severe winter.

(339.) The general influence of climate in accelerating or retarding the fructification of plants and the ripening of their seeds, will be best exemplified by the periods at which the wheat harvest commences on an average of years, in different latitudes, which we find stated by Dr. Balfour as follows :—

Localities	Mean Period of Sowing.	Mean Time of Harvest.	Difference in Days.
Malta . . .	Dec. 1.	May 13.	162
Palermo . . .	Dec. 1.	May 20.	170
Naples . . .	Nov. 1.	June 2.	195
Rome . . .	Nov. 1.	July 2.	242
Berlin . . .	...	...	299
Alps (3000 ft.) .	Sept. 12.	Aug. 7.	329

Owing, however, to the comparatively higher summer heat in Sweden, and the more rapid vegetation than in England, the wheat harvest at Upsala is not later than that in the south of England; and barley ripens ten

extraordinary summer of 1859, in my own garden at Hawkhurst, the *Paulonia imperialis* not only flowered, but ripened its seed, which germinated and produced an abundant crop of vigorous plants.—H.]

days earlier. According to M. Berghaus (*Alm. de Gotha*, 1840) the time of *flowering* of plants in general is retarded by 34 days, by an increase of 10° in latitude in the north of Europe, by 40 days in the more temperate countries, and by 74 days (for a similar increase of latitude) in south Europe and Asia Minor. M. Quetelet (*Probab.* 172) assigns 5 days for the general retardation of flowering due to 100 yards of elevation above the sea.

(340.) The local distribution of genera and species of plants over the globe tends very strongly to suggest the idea, now become prevalent among botanists, of specific centres in which they have had their origin, and from which they have spread, by divergence in all directions, till intercepted in their progress of propagation by some insuperable barriers, whether of climate, soil, or sea. The greater or less areas over which they have so spread, have, of course, been determined by the natural facilities for the dissemination of their seeds by winds, by birds, or by water transport; while mountain ranges have in some cases supplied, as it were, stepping-stones for traversing regions the plains of which are not adapted to their growth. This taking place at an earlier geological epoch, when much that is now sea was land, and when a continuity existed between countries now widely divided, affords a satisfactory explanation of many otherwise unaccountable phenomena. Thus, for example, we find the flora of Iceland to be nearly iden-

tical with that of the Scandinavian mountains. Europe and North America have many plants in common. The flora of the mountain districts of west and south-west Ireland, as Prof. E. Forbes has shewn, is similar to that of the north and west of Spain; that of the loftiest British mountains refers itself to the same origin with that of the Scandinavian Alps. Thus, too, the chain of the Andes has afforded a line of communication of identical species from the equator to the very extremity of Terra del Fuego. The only question at issue is, as to the singleness or multiplicity of these specific centres in the case of one and the same species. Professor Schouw contends for the latter view of the subject, grounding his reasoning on the fact of identical plants appearing in regions so very far remote and separated by such natural obstacles, as to render the idea of migration untenable, as when, for instance, we find European plants, such as Phragmites communis, Alisma Plantago, and others, in America, New Zealand, and Van Dieman's Land, and not in intermediate countries. Sir W. Hooker has enumerated more than thirty antarctic species, as identical with European ones.

(341.) The total number of plants known to exist has been estimated by Dr. Balfour at 120,000, and those actually described, at 96,000, viz., of acotyledonous plants 15,000, monocotyledonous 14,000, and dicotyledonous 76,000. These, however, differ in their relative propor-

tions to each other widely in different quarters of the globe. The lower forms of vegetation, the acotyledons, bear a larger proportion to the others in polar and alpine regions. In equatorial regions, the monocotyledons are to the dicotyledons as 1 to 5 or 6, in temperate as 1 to 4, and in cold climates, as 1 to 3. In the extreme climates of the arctic islands, however, the proportion diminishes, while on the other hand, in the antarctic islands, they are comparatively much more numerous; the ratio in Kerguelen's island, being as 1 to 2, and in Lord Auckland's group, according to Hooker, 1 to 2·2. In central and southern Europe the proportion is 1 to 4 on the plains, decreasing with increase of altitude up to 8500 feet, where it is 1 to 7. Among the monocotyledons gramineous forms especially flourish in temperate and cool climates.

(342.) Ferns bear the least proportion to phænogamous plants in the middle temperate zone, where they form about 1-70th of the whole flora, the ratio increasing both towards the equator and the poles. In the low plains of the great continents within the tropics they amount to 1-20th, while in their mountainous districts the ratio is as high as 1 to 7. The proportion of ferns attains its maximum in small islands situate in great oceans. Thus in Otaheite their proportion to phænogamous plants is as high as 1 to 4, and in St. Helena and Ascension as 1 to 2.

(343.) Among the phænogamous plants, the orders f gramineæ, cyperaceæ, and juncaceæ, increase in pro-ortion to the rest as the latitude increases. The reverse ; the case with the rubiaceæ, leguminosæ, euphorbiaceæ, nd malvaceæ, while the natural orders of cruciferæ, mbelliferæ, and compositeæ, are comparatively more bundant in the temperate latitudes, the proportion of e latter rising as high as 1 to 6 in the temperate gions of America.

(344.) The following classification of plants, according › their climatic distribution, specifying those families hich are more especially characteristic in each zone, as been given by Von Humboldt, in illustration of the ifferent aspects of vegetation presented in ascending a fty equatorial mountain, in which the several zones are aversed in rapid succession. Here we find that the—

Region of	Corresponds to the
Palms and Bananas	Equatorial Zone.
Tree Ferns and Figs	Tropical Zone.
Myrtles and Laurels	Subtropical Zone.
Evergreen Trees	Warm Temperate Zone.
Deciduous Trees	Cold Temperate Zone.
Pines	Subarctic Zone.
Rhododendrons	Arctic Zone.
Alpine Plants	Polar Zone.

he zones here in question are not limited by parallels f latitude, nor by the mean isothermal lines, but rather y those which we have called isotheral, or those which ave an equal mean summer temperature, so as to pre-

sent on the globe undulated outlines comprising between them plants which have a certain general resemblance. These therefore have been denominated Homozoic zones by Professor E. Forbes. Their limits, however, are necessarily ill defined, as they overlap or run into each other by a community of more or fewer genera and species, and in greater or less abundance of individuals of each such conterminous species.

(345.) The equatorial zone, according to Dr. Balfour, besides the palms and bananas, which may be regarded as its most abundant characteristics (including the cocoa-nut and plantain), comprehends also arborescent grasses, orchidaceous plants and lianas, the coffee-trees, the ginger and its congeners, together with the cinnamon, the nutmeg, and other rich spices. The baobab (Adansonia digitàta) of Senegal, the most massive, and supposed to be among the longest-lived of trees, is a native of this zone, as are also many others of gigantic growth, and of great commercial importance, as the mahogany-tree of Honduras and Cuba, the locust-tree of the West Indies, the logwood, the mora of Guiana, and the ebony; and among edible products, the pineapple, breadfruit, and the finest of all fruits, the mangosteen (Garcinia Mangostana), a native of Malacca.

(346.) In the tropical zones, besides the tree ferns and ficus family, to which the banyan of India belongs, which are its predominant characteristics, we find the

piperaceæ (pepper and its congeners), melastomaceæ, and convolvulaceæ, among which the C. Batatas or sweet potato, is among the most useful. The yam also (dioscorea) belongs principally to this zone, as does also the teak, one of the most valuable of timber trees.

(347.) In the subtropical zones few palms occur; we find in it, however, the date palm of Egypt and North Africa, and the Chamærops Palmetto, which extends even into Sicily. These, however, are the zones *par excellence* of the euphorbias and cactuses, the magnolias, proteas, heaths (erica), and their Australian representative, the epacridaceæ. The zamia and cycas also occur. This zone is remarkable for the enormous growth of several of its timber trees. In California (included in it) has been discovered the Wellingtonia gigantea, the loftiest and grandest of trees, said to attain the almost fabulous height of 400 or even 500 feet, with a diameter of forty or fifty feet near the ground. The Californian pine (Abies Douglassii) is also of enormous stature, sometimes attaining 245 feet in height, with a circumference of 57 feet three feet from the ground. The Araucaria imbricata of Chili also attains the magnificent altitude of 260 feet, the Norfolk Island pine (Eutassa excelsa) 224, the Snuglok (a species of tropical oak in the Valley of Teesta, in Sikim) 200, etc.

(348.) Besides the evergreen oaks in the south of Europe, we also find in the warmer temperate zones, in

perfection, the esculent fig, the orange, the pomegranate, and the vine, with numerous species of cistus, vaccinium, smilax, and melaleuca.

(349.) In the colder temperate zone we find the vegetation so familiar to us in England and in north Europe—the oak, the ash, the beech, the chestnut, and the walnut; great forests of coniferæ, the hemlock spruce, and the sugar maple of the American forests. In the southern hemisphere the blue gum-tree attains a gigantic size in Van Diemen's Land. Elwes (*Tour round the World*, p. 268) records a specimen in Lory Bay 27 feet in girth at five feet above the ground, a quite straight tree, which would square 2 feet 6 inches at 200 feet, and containing five thousand cubic feet of timber!

(350.) The subarctic zone is that of coniferæ, willows, birch, and poplar. In the valley of the Black Irkut, in Siberia, Atkinson found a ravine filled with ice, and large poplars growing in it, with their trunks imbedded 25 feet in snow and ice, while the branches were in full leaf. Around each stem was a hollow of 9 inches, thawed and full of water.

(351.) In the arctic zone the willow, the birch, and the alder are dwarfed. The Pinus sylvestris and Abies excelsa in north Europe; rhododendrons, azaleas, and andromedas in North America, with some grasses and numerous lichens and mosses, also occur.

(352.) Finally, in the polar zone neither trees nor bushes, nor any cultivable esculent plants can exist. Yet Melville Island produces 67 species of flowering plants, and Spitzbergen 45. Kane found 22 species at Sylvia Headland in 78° 41′ N. lat. Saxifrage, dryas, papaver, ranunculus, juncus, potentilla, salix, and some other genera, are enumerated as among the plants of these regions. In the southern hemisphere the vegetation of the sub-antarctic zone is confined to a few cryptogamous plants, and that of the antarctic and polar zones may be considered as *nil.*

(353.) Botanists, however, have considered the distribution of plants under another and more special point of view, taking account, not so much of the general contents of the zones of climate, as of those regions or districts over which particular families of plants prevail in their fullest state of development, or to which they are exclusively confined. Of these distributions, perhaps, the most generally received is that of Schouw, who divides the surface of the globe into regions, on the principle that, to constitute a botanical "region," at least one-half of the *species,* and one-fourth of the *genera,* of some one or more natural families of plants, should be peculiar to it, and that individual *orders* should either be peculiar to, or reach their maximum in it. Where this condition is either imperfectly fulfilled, or the flora of a district, though evidently peculiar, is not sufficiently

known to afford a phytological designation to it, the "region" must be accepted as a provisional one.

(354.) The first botanical region thus marked out is nearly co-extensive with the polar and arctic zones of the former subdivision, including all the land within the polar circle and the northern parts of the two great continents, from the ice down to the zone of trees; and the upper parts of the European mountains and those of North Asia, down to the arborescent belt. *Saxifrages* and *mosses* are the especial characteristics of this region, gentianaceæ, caryophyllaceæ, cyperaceæ, and salicaceæ, also abound. In the northern portion of this region carices predominate. On the more southern alpine heights primroses and campanulas appear. On the warmer borders of this region forests of fir and birch, to the exclusion of other trees, begin to present themselves.

(355.) The region which extends in northern Europe and Asia from the warmer limit of the former down to the Pyrenees, Alps, the Balkan, and Caucasus, and the Altai range of mountains, is especially characterized by the predominance of *umbelliferous* and *cruciferous* plants. In this region also, (which is nearly conterminous, in the quarters of the globe to which it belongs, with the zone of deciduous trees) coniferous and amentaceous trees abound; and of shrubs and other plants, the families rosaceæ, ranunculi, carices, and fungi, are largely

developed. In its north European portion, chicoraceous plants abound (the dandelions and their congeners), while in southern Asiatic Russia and the countries bordering on the Caucasus, Cynarocephalæ (the thistle and artichoke tribe) and astragali, as well as many saline plants, appear as prominent features. The cultivated plants are those of the temperate zones.

(356.) The next botanical region may be considered as including the Mediterranean flora, that is, of south Europe, Asia Minor, and north Africa, down to the Desert, the Canaries, and Madeira, with exception, of course, of the Alpine heights, which belong to the first region. Here stand prominent the *labiatæ* and *caryophyllaceæ* (families of which the blind nettle and pink afford instances). This within its limits, coincides with the zone of evergreen trees, and nourishes those fruit-bearing trees enumerated in our account of that zone. Rice also and millet, cotton, guinea corn, and the almond, are here cultivated. The cistus abounds in Spain and Portugal; the aromatic labiatæ and scabiosæ in France and Italy; the shrubby labiatæ in Greece and Asia Minor; the oleander adorns the Mediterranean coast, and many balsamiferous and gum-yielding trees and shrubs flourish in Asia Minor and North Africa. In the Canary Isles the family of houseleeks (sempervivum), and in Madeira arborescent heaths are common. Four-fifths of the Azorean species are European, the remainder

are peculiar to the Atlantic islands. A specimen of the Dracæna Draco, on Teneriffe in the Canaries, is said to be the oldest existing tree.

(357.) The flora of the eastern portion of North America, from the limits of the arctic region to the 36th parallel differs from that of the corresponding district in Europe in the paucity of umbelliferous, cruciferous, and cynoracephalous plants; in the absence of heaths; and in the predominant abundance of *asters* and *solidagos*. Maize is much cultivated in the southern part of this region. Among its forest trees occur the hemlock-spruce, and the sugar-maple, the hickory, the tulip-tree, and the liquid amber, as well as many peculiar and magnificent oaks and others, which in autumn assume the most vivid tints of red and yellow. Kalmias, azaleas, rhododendrons, hydrangeas, and other richly flowering shrubs, occur also in great abundance.

(358.) The western flora of North America, down to the same parallel, is less known, and constitutes a region apart—that of California, Oregon, Vancouver's Island, and Russian America. It is remarkable for the beauty and brilliancy of colour of its flowers, among which the eschscholzia would seem to have imbibed the quintessence of the Californian gold. The nemophilas, clarkias, and innumerable others of this region, have become the pride of our gardens. But it is chiefly in the grandeur of its timber-trees that this region

stands conspicuous. The Wellingtonia or "Mammoth tree," has already been mentioned (art. 347), and a vast number of peculiar coniferæ, such as the Abies balsamea, grandis, alba, canadensis, Douglassii, the Pinus ponderosa, Lambertiana, insignis, Fremontiana, and many others, of which A. grandis attains the height of 224 feet, A. alba 160, P. Fremontiana 224, and Lambertiana 235, The Thuyia gigantea of the Rocky Mountains attains 200 feet. Many of these thrive well in England.

(359.) The southern region of North America, which may be called, *par excellence*, the region of *magnolias*, is distinguished from the corresponding region of the old continent by the paucity of labiate and caryophyllaceous plants. Its trees have broad shining leaves and beautiful flowers. The tulip-tree here attains 120 feet in height. Here, too, we have the long-leaved pitch pine (one of the most picturesque of trees), clothing the "pine barrens," while the swamps of the southern states produce the deciduous cypress, the aquatic oak, and the swamp hickory. Among the more beautiful and curious of the flowers are the Nelumbium luteum and the Dionæa Muscipula. The forests of Florida and Alabama are hung with air-plants (Tillandsia usneoides). In this region also many tropical forms occur—zinziber, cycas, cactus, anona, etc. Of 2891 species of phænogamous plants in the United States, only 385 occur in northern or temperate Europe.

(360.) In the subtropical, or warm temperate region of east Asia, from the 30th parallel northward, comprehending Japan, the north of China, and Chinese Tartary, plants of the order *ternstrœmiaceæ* (tea and its cogeners) and *celastraceæ* chiefly abound. Camellia, thea, citrus, rhamnus, and lonicera, occur abundantly, the two latter in Mantchouria so much so, as to give a peculiar character to the vegetation, and to merit for it the name of the region of *rhamni* and *caprifoliaceæ.* The flora of this region is, in many respects, intermediate between that of the Old and New World. The loquat, the tallow-tree (Stillingia sebifera) the camphor-laurel, and the Westeria sinensis, are natives of this region. The south of China forms a distinct region, having many peculiar plants, among which the rice-paper plant of Formosa, and that delicate fruit, the litchi, may be mentioned.

(361.) The flora of India, Ceylon, and the south-eastern Asiatic peninsula, to the height of 4000 or 5000 feet, is more expressly marked by the number of *zinziberaceous* plants, by leguminosæ, cucurbitaceæ, and tiliaceæ. Here also we find the cocoa-nut, the mangosteen, cinnamon, cloves, turmeric, indigo, cotton, and pepper Teak is abundant in the Birman Empire and on the Malabar coast. The varnish-tree and that which produces the stick-lac; mangroves, casuarinas, immense bamboos, the satin-wood, (Chloroxylon Swietenia), the Borassus flabelliformis, a magnificent palm, said to grow

100 feet high, and to produce leaves large enough to shelter twelve men, and the Amherstia nobilis, the most magnificent of flowering trees belonging to this region.

(362.) The mountain country south of the Himalaya, to the height of 10,700 feet, including the Sub-Himalayan provinces of Upper India, form a region which has some European plants. Ranunculus, nasturtium, veronica, and polygonum, mix with a rich vegetation peculiarly Indian. Here occur the Cedrus deodara, supposed by Hooker to be a variety of that of Lebanon, sometimes attaining 200 feet in height and 36 in girth; the Pinus excelsa, Webbiana, longifolia, and others. In the higher portions of this region are found species of oak, rhododendron, berberis, and primula; in the lower, many tropical plants. In the valleys of the Central and East Himalaya, arborescent ferns and orchids occur in great luxuriance. The Saul wood too (Shorea robusta), that dreadful poison the Aconitum ferox, and that most beautiful of magnolias (M. insignis), are natives of this region. India abounds with urticas (nettle), the sting of some of which, as U. crenulata, is most formidable in its effects.

(363.) To the region of the Asiatic islands, including those of the Indian Ocean and those between the Eastern peninsula and Australia, below the altitude of 5000 feet, belong most of the plants of tropical India, with many peculiar ones, as the Carica papaya (papaw-tree), which occurs also in central America, the Jatropha

manihot, the bread-fruit, coco-de-mer, the poisonous upas of Java, and a nettle even more formidable than Urtica crenulata, whose sting sometimes produces death (the Daoun Satan or Devil's leaf of Timor) as well as that of Sumatra, called tenacissima, which makes excellent cordage. The Rafflesia Arnoldi of Sumatra, a parasitical plant, bears the largest of flowers, being 3 feet 6 inches in diameter. Orchideæ and other parasites load the trees in the rank forests of Java, and ferns also are abundant. This is especially the region of spices. The forests produce an infinite variety of useful and ornamental woods. In Borneo are found the Dryobalanops camphora and the Pandanus odoratissimus or screw pine, a tree with buttress-like roots, every branch of which terminates in an enormous head, like the pine-apple plant. The sugar-cane is cultivated in Mauritius and the whole character of the vegetation of this region is rich and luxuriant beyond imagination.

(364.) The higher portions of this district, where it exceeds 5000 feet in altitude, has a flora of its own, nearly allied to that of the higher elevations of India, in which extratropical forms replace the tropical, and where we find forests of various species of oak, podocarpus (a species of yew), plantagos, gentians, and vaccinia, and other genera of colder regions.

(365.) The islands of the Pacific (Oceanica) form a region the character of whose vegetation partakes of the

Asiatic and Australian. Of their 214 genera, 173 are found in India. In the Sandwich Islands nearly one third of the vegetation consists of ferns. No less than 50 varieties of bread-fruit, the paper mulberry, the Dracæna terminalis or ki, which supplies food and an intoxicating drink, the Tacca pinnatifida or Otaheite saleep, which produces a starch, with several other peculiar, fruit-bearing trees and esculents are found here. Lobelias, grapes, sedges, myrtles, and arums also abound. In common with the Australian flora, we find in this region species of casuarinæ, proteaceæ, epacridaceæ, and acacias.

(366.) The Arabian region, which includes that part of the Asiatic continent stretching across Persia and Afghanistan to the plains of north-west India, is more especially characterized as that of balsamic trees, mimosæ, acaciæ, balsamodendron, and amyris. The coffee, the sensitive plant, numerous species of ficus, senna, etc., are also products of this region. The Boswellia serrata produces frankincense. *Coffee* is supposed to be originally a native of Abyssinia, where in *Kaffa* it forms dense thickets.

(367.) The Desert region, comprising the sandy wastes of Africa and Syria, as may easily be supposed, is poor in plants. It has no peculiarly characteristic genera, and the species which chiefly inhabit it are those of acacia, mimosa, cassia, and zygophyllum or caper-

bean, the date-palm, and the dourra (sorghum) supply food, and the pennisetum grass and Alhagi maurorum form the chief support of the camel.

(368.) The flora of tropical Africa is but imperfectly known. Leguminous, rubiaceous, and cyperaceous plants abound throughout. On the west coast we find the baobab and the palm-oil plant (Elais guineensis), ground nuts, and the akee (Cupania sapida), the envelope of whose seed is eaten, the kola nut, the Pentadesma butyracea, the butter and tallow tree of Sierra Leone, and the poison bean of Calabar. On the east coast the distinguishing genera are danais, ambora, dombeya, and senacia. Cotton, indigo, tobacco, the sugar-cane, ginger, yams, cassada, bananas, cocoa-nuts, papaws, oranges, pine-apples, and many others, form the rich catalogue of vegetable delicacies and commercial treasures furnished by this important region.

(369.) Central America (including Mexico and South America to the Amazon river, from the sea level to 5500 feet in altitude) is the region especially characterized by *cactuses and piperaceous plants.* In the West Indian isles, ferns and orchideous plants also prevail. In Panama besides these, we find abundant leguminosæ, melastomaceæ, compositæ, and cinchonaceæ. That noble flower, the Victoria Regia, occurs in this region, and in all the warmer parts of south-eastern America. The lower parts of Mexico, Guiana, New Granada, and

Peru, abound in palms. The vegetable-ivory palm is a native of the last-named province. The Anona Cherimolia, or Peruvian pine-apple, is celebrated. Indeed this region is the original *habitat* of the pine-apple. The fragrant vanilla, and that kind of vanilla called chica, are cultivated in this province, with the Theobroma cacao or chocolate. The sugar and tobacco culture of the West India islands is too well known to need mention. The agave, or American aloe, which yields the pulque wine, the custard-apple, and guava, the cassava or manioc, and the capsicum; among woods, the Hymenæa Courbaril, or copal tree, logwood, mahogany, etc.; and among poisons, the ourali or woorara (Strychnos toxicaria), are also indigenous in this most rich and productive region.

(370.) The Mexican highlands (above 5500 feet) offer, of course, the prevailing families of the colder countries. Many peculiar coniferæ, as the Pinus religiosa, Apulcensis, Hartwegii, and Montezumæ, sixteen species of quercus, and the deciduous cypress, (which here attains a height of 120 feet, and 30 or 40 feet in girth) grow here.

(371.) Between 5° and 20° S. lat., and the altitudes 5000 and 9600 feet in the Cordilleras of the Andes, the *cinchonas*, which yield the medicinal alkaloids, quinine and cinchonine are found almost exclusively. The Ceroxylon andicola, which produces wax on the surface of its stem, and the Chenopodium Quinoa, a Peruvian

plant, affording a nutritious meal from its seeds, are native here.

(372.) The still loftier elevations of the Andes are particularly rich in *escallonias* and *calceolarias*, associated with many alpine plants. The cultivated vegetation of the warm temperate zone is not altogether absent from this region, since we find the vine, the orange, and the olive succeeding well in La Paz, on the plateau of Bolivia, 12,260 feet above the sea level. (K. Johnston.)

(373.) The basin of the Amazon river, and the upper part of that of the Parana, comprising the portion of South America east of the Andes from the equator to the southern tropic, is rich beyond description in every form of forest vegetation. *Palms* and *melastomus* are its more characteristic forms. We have reeds of 100 feet high, grasses of 40, and tree ferns. The magnificent forest trees are covered, and in some cases stifled, with overwhelming masses of parasitical creepers, with orchideæ, araceæ, tillandsias, epiphytic cactuses, peperomias, and gesneras, or with lianas, including bignonias, passifloras, and aristolochias, etc. The Eriodendron saumauma (which, from its habits, ought to be called Excelsius), puts forth no branches till it has overtopped every other tree of the vast Amazonian forests, over which it then predominates unrivalled. The Siphonia elastica, which yields caoutchouc, is indigenous in Brazil. That wonderful product, the coca leaf or ipadu (from

the Erythroxylon coca), is obtained from the tropical valleys of the eastern slope of the Andes. The yerba maté, or Paraguay tea, represents in its general use, as it partakes in its properties, and in the presence in it of *theine*, the tea plant of China.

(374.) Extra-tropical America, from the southern tropic to 40° S., including South Brazil, La Plata, and Chili, is more especially the region of *arborescent compositæ.* Its flora exhibits an approach to those of South Africa and Australia, in the families of protea, polygala, oxalis, araucaria, and goodenia. That superb tree, the Araucaria imbricata, which may be also considered as a valuable fruit tree, is a native of Chili, as are also some species of arbor vitæ. The chief approximation of this region is European, more than half its genera being common to both. The vine and peach are cultivated. The potato is found wild both in Peru and Chili. The loasa, a stinging climber, has been introduced into our gardens from the latter.

(375.) The portion of America south of this, with the Falkland and other antarctic islands, constitutes another region in which the forms of the northern and arctic zones prevail. A greater number of plants, in Terra del Fuego, identical with, or nearly allied to those of Britain occur here, than in any other part of the southern hemisphere. Some of the beech trees are peculiarly beautiful. The Flora of the higher mountains is European. Evergreen plants prevail, and the fuchsia,

in winter, presents a singular spectacle — arborescent, and covered with snow, while still green, and frequented by humming birds (King). The Falkland islands are treeless, but rich in the vegetation of the tussac grass and bolax globaria, which forms dense round balls, or sometimes a dense bushy mass, along the top of which it is practicable to walk when impenetrable to the traveller at the ground level. The character of the antarctic islands, south of these, is one of utter desolation. In Kerguelen's Land only eighteen species of flowering plants exist.

(376.) South Africa has a very peculiar and striking character of vegetation. The *mesembryanthemum* and *stapelia* families are especially abundant, but little conspicuous in comparison with the heaths which there luxuriate in astonishing profusion, as well as the geraniums and pelargonia. Innumerable bulbous genera and everlastings clothe the sandy flats and mountain terraces with beautiful flowers; and the proteaceæ form a rich and peculiar feature, especially the P. (leucodendron) argentea, with its silver-silky leaves. The heaths and proteas are chiefly abundant in the most southern districts. Northward, thorny acacias abound, among which the "wait-a-bit" (A. detinens) is the traveller's plague, with a profusion of aloes and great succulent euphorbias, which attain a tree-like development. In the desert plains of Latakoo, Burchell

describes scanty plants not two feet high, with hard woody stems, and two or three centuries old, which abide their time to put forth a transient life on the few and far-between occasions (sometimes several years asunder) when rain falls. The flora of South Africa is connected with that of Australia by the links of the proteæ, restiaceæ, iridaceæ diosmas, and others.

(377.) The vegetation of Australia is also exceedingly peculiar. Taken as a whole, it has been characterized as the region of *eucalypti* and *epacridaceæ*, which latter represent, in this continent, the heaths of the old world. "Several entire orders of plants are known only in Australia, and the genera and species of families which grow elsewhere assume new and singular forms. Persistent-leaved trees, with hard, narrow leaves of a sombre, melancholy hue, are prevalent, and there are whole shadowless forests of leafless trees, the footstalks of the leaves, dilated and set edgewise on the stem, supplying their place. Plants in other countries have glands on the under-side of the leaves, but in Australia there are glands on both sides, and the changes of season have no influence on the unvarying olive green of the Australian forests. Even the grasses are distinguished from those of other countries by a remarkable rigidity."—(Mrs. Somerville.) Among the Australian forms are many proteaceæ. Nearly half the known species of this order grow in the parallel of Port Jackson on both coasts. There are 100 species

of eucalypti, and 93 leafless acacias. Casuarinas, with long-jointed, drooping branches, afford the principal timber; and the Norfolk Island pine (Eutassa excelsa) is one of the most superb of trees. The roses of the old world are replaced by banksias, which are already naturalized in our gardens.

(378.) New Zealand furnishes another, and the last, of those botanical regions. Its flora connects itself with that of Australia, South America, and the Pacific islands. Out of 1900 or 2000 species of plants it contains, only 730 are flowering ones, and of these, two-thirds are absolutely peculiar to it. Of the rest, according to Hooker, 193 species are Australian, 89 South American, 60 European, and 50 antarctic. The Phormium tenax (New Zealand flax), is a very valuable product. 120 ferns, some arborescent, rising to a height of 40 feet, occur. The forest trees are peculiar, and furnish excellent timber, the Kauri pine being one of the most remarkable. One palm only grows here, the Areca sapida, and, among flowering trees, the Metrosideros tomentosa is remarkable for its rich crimson blossoms.

(379.) *Marine Vegetation.* It would lead us too far to enter into any particular account of marine botany. Like that of the land, it has its regions:—1. Northern; 2. North Atlantic; 3. Mediterranean; 4. Tropical Atlantic; 5. Antarctic; 6. Australian and New Zealand; 7. Indian Ocean and Red Sea; 8. Japan and China Seas;

9. Pacific. The sargasso, or gulf-weed, forms a mass of almost continuous vegetation in the Atlantic, covering 260,000 square miles. The Macrocystis pyrifera is of universal distribution; wherever the sea is exempt from ice, it occurs in immense masses, at a mean depth of 6 to 9 fathoms. Individual plants attain 700 feet in length. Fucoideæ abound in the higher north latitudes, and cystophora in southern. The lavers of the British Seas (as if to carry out the general resemblance noticed in art. 375) occur at the Falkland Isles, where also is found the Durvillæa utilis, "a vegetable cable several hundred feet long, and as thick as the human body."

(380.) In depth, according to Professor Forbes, one great zone lies between the high and low water marks; a second (the region of fuci and laminariæ), from low-water mark to 7...15 fathoms. Ordinary algæ exist only within 50 fathoms of the surface. In the Mediterranean and Ægean seas, marine vegetation occurs at the depth of 100 fathoms.

(381.) *Cerealia.* Wheat has been lately referred by M. Fabre, as its origin, to the Ægilops ovata, a native of the south of France and the Mediterranean coasts, which by careful culture he finds to shoot into varieties, and these again into others more and more nearly resembling wheat, till, after fifteen or sixteen years, a true wheat results. The conclusion, however, has been still more recently more than called in question by Dr. Godron,

who considers the case one of hybridization from neighbouring wheat fields (*Jour. R. Agricult. Soc.* xix. 108). Wheat will not yield produce within the tropics at the sea level, at least during the hotter season, though, in the colder months, it may be grown a few degrees nearer the equator. Its northern limit is 58° N. in Britain, 64° N. in Norway, 60° in Russia, and lower in Siberia. In Chili and Peru it grows luxuriantly at 8500...10,000 feet above the sea. Humboldt saw a wheat plant in Mexico with 70 stalks, some bearing ears of 100 grains. *Barley can be grown as far north as 70° in Lapland,* and 68° in Siberia; on the Alps as high as 3500 feet, and on the Himalayas, up to 12,000. Rye has its northern limit in Norway at 67°; in Siberia, perhaps 68. Fraser found large fields of it, and of Buckwheat, at 11,405 feet, near the temple of Milun, in the Himalaya. Rice can only be cultivated where a high mean summer temperature (not under 73°), and such an excess of moisture as actually to flood the fields, combine; for which artificial irrigation is almost always resorted to. In India and China it is the universal food and chief support of their teeming populations. In Ceylon alone there are one hundred varieties of rice used, and thirty of Millet, which is cultivated, for the most part, in southern and western Asia and north-eastern Africa, also to some extent in Italy, and even so far north as Bagneres de Bigorre, in the Pyrenees, where we have

seen it growing. MAIZE was brought from America by Columbus, in 1493; and has since been propagated very extensively: its colder limit is the isothermal line of 65°.

Distribution of Animals.

(382.) The distribution of animals on the earth, like that of plants, is far from being solely determined by the conditions of a suitable climate and sufficient food. The evidence of radiation or dispersion from local centres or primary *habitats*, is of the same nature, and equally cogent as in the case of plants, though modified by the locomotive powers of animals. We find the indigenous Faunas of the Old and New Worlds, of Australia, and of many islands, separated from each other by quite as strong lines of demarcation as their Floras; and that not by reason of any peculiarity rendering the soil or climate of the one unsuited to the indigenous animals of another. On the contrary, the animals of one region, when introduced by man into another not too different in climate, are usually found to multiply with extraordinary rapidity. The Pampas of South America swarm with wild cattle and horses, the descendants of European breeds. Strayed oxen in Australia have been found multiplied into vast herds; the sheep has proved prolific there beyond the most sanguine hope; and already the song of the nightingale and the lark has begun to be heard in its woods.

(383.) Another point of resemblance in the distribution of these two great divisions of organic creation is found in the fact that, though the species differ, yet many families and genera are represented in the several zoological regions, even those most independent, by genera and species, bearing a certain considerable parallelism or representative relation to them. Thus the lion and tiger of the Old World are represented by the puma and jaguar of the New, both belonging to the same genus (felis); the crocodile of the Nile by the cayman of the Orinoco; and the seals of the Arctic Ocean by other seals resembling them in general form and in all their habits, though specifically different, in the Antarctic. In the New World we find, it is true, no pachydermata provided with trunks like the elephant, but an approach to that form is preserved in the tapirs, of which South America produces two species, strongly allied in form and habits to the Malayan tapir, though specifically distinct. Even in the Old World we find species distinctly localized, to the mutual exclusion of each other. Three species out of four of the African rhinoceros have two horns, the Asiatic only one. The Asiatic and African elephant are quite distinct from each other, and both from the Siberian elephant (primigenius) which, though now extinct, evidently existed there during the geological epoch in which we are now living. In the inferior forms of animal life we find examples of

a similar and almost startling kind. In the Mammoth Cave of Kentucky occur three genera of *eyeless* insects (anophthalmus, adelops, and bathyscia), members of a subterranean fauna, whose common character consists in *blindness*. And these generic forms are found to be reproduced in the limestone caverns of Carniola, and that in the case of anophthalmus, with an approximation almost amounting to specifical identity (*Schi dte Specimen Faunæ Subterraneæ*). We find, too, cases of restricted localization quite as marked as any afforded by the vegetable kingdom. That the chamois and ibex should be peculiar to the Alps, and the llama to the Cordilleras and high plateaus of the Andes, may not appear extraordinary when the habits of these animals, in keeping to the loftiest summits, are considered; but the limitation of an active insect, well formed for flight (Glossina morsitans, the Tsetze fly), to a limited district of small extent in South Africa, marked out by no apparent natural boundary, yet so definite, that for a horse to cross a well-known line is certain death (the trial has been deliberately made—*Livingstone*, p. 81, 82), assuredly does seem very astonishing.

(384.) The great majority of animated beings are confined to zones of temperature more or less restricted according to their organization, few only (man and those domestic animals which he has succeeded in acclimatizing) being capable of resisting the two extremes of

temperature. And within these limits, among herbivorous animals, the botanical limits which restrict the growth of their habitual food constitutes another boundary, which may or may not be conterminous with the former, though few animals of higher organization than insects are restricted in their range of food to a single or to a very few species of plants. The carnivora have, however, in this respect a wider range, their limit of food being no other than that placed by the absence of animal life itself. Thus we find in the neighbourhood of the Baikal lake both the Fauna and Flora of hot and cold regions intermixing. At Nertschinsk the wild peach grows near the dwarf birch, and the tiger and the bear range the same forests. The former finds his way even to Barnaoul, crossing the Kirghiz steppes and the Irtisch river for prey.—(*Atkinson.*)

(385.) The total number of species of animated creatures known to exist in the present state of the world may be roughly stated at about 155,000, which zoologists have classed as follows:—

1. Vertebrata, viz.:—	Species.
Mammalia, about	1,700
Birds	6,000
Reptiles	1,500
Fishes	6,000
	15,200
2. Mollusca	10,000
3. Articulata, including insects	120,000
4. Radiata	10,000
	155,200

Of these the number of existing mammalia may be considered as pretty accurately known, and of birds with some approach to certainty. The number of reptile species, whose *habitat* is determined, and of which scientific descriptions have been published, is set down by K. Johnston at 657, and 1500 is perhaps a somewhat large estimate for what may be considered as *known* reptiles. The articulated animals, which are all, in common parlance, classed as worms and insects, are no doubt as yet but very inadequately known, and such large additions to them are yearly made, that it is very likely the real number may be double of that set down. As for the last class, comprehending, as it does, the countless multitudes of infusoria and polypes, the number here assigned is doubtless a most inadequate one. In stating the species of existing animated organisms at 200,000 we are probably within the mark, and if fossil species be included, even this large number may perhaps be doubled.

(386.) It will be impossible, within the limits of this essay, to do more than indicate some of the leading facts relative to the distribution of the more interesting to man among these classes of animated beings. Of these the MAMMALIA claim the first place. They are divided by naturalists into eight orders: Quadrumana, Marsupialia, Edentata, Pachydermata, Carnivora, Rodentia, Ruminantia, and Cetacea. The *Quadrumana* (apes, monkeys, baboons, gibbons, etc.) are divided be-

tween the Old and New World in the proportion of 14 genera and 111 species in the former, to 9 genera and 91 species in the latter, none of the genera being common to both. They are all tropical animals, the great majority being denizens of the torrid zone. One species only, the Barbary ape, is found in Europe (Gibraltar), one only so far north in East Asia as the Isle of Niphon, in lat. 38°; two south of the Orange River, in South Africa, while, in South America, a few extend as far as 38° S. Australia possesses none. The small monkeys, called *makis*, or Prosimiæ (the lemurs, lorises, etc.), are chiefly natives of Madagascar and the neighbouring Mozambique coasts. The Gorilla, the most formidable of the apes, is limited to a very narrow region of Central Africa,* which European, and we may add, American research has only just succeeded in developing. The ourang-outang is a native of Sumatra and Borneo, and its African congener, the chimpanzee, the most gentle, human, and intelligent of them all, inhabits the forests of south-western Africa between Cape Negro and the Gambia. The brown monkeys of the New World (the sapajous and sajuans) are, for the most part, smaller and less ferocious than the Simiæ of the Old, and differ from them in their system of dentition and the absence of cheek-pouches. Their chief *habitat* is in the forests of Brazil and Guiana.

* On the Mani River, and between the Gaboon and Cape Lopez, according to the accounts of M. Du Chaillu.

(387.) The *Marsupials* (or those which carry their young in pouches, including the opossums, kangaroos, wombats, phalangers, etc.) constitute 14 genera, including 123 species. Of these only one genus, the opossum, is found in America, distributed, in 21 species, over the whole continent, from Canada to 36° S. All the other genera belong exclusively to Australia, Van Diemen's Land, and the islands of the Asiatic archipelago, as far as Java. In Australia they constitute an immense majority of the mammalian species, in which, with this exception, that singular continent is exceedingly poor. In the islands of the Archipelago only seven species are enumerated, among which one kangaroo is said to occur (in Java). In no other part of the Old World are any marsupial animals belonging to this class found living; and if we would seek for indications of them, singularly enough it is in the fossil remains in the oolites of the south of England, the antipodes of the region which they now almost exclusively possess.

(388.) The genera of edentata, or toothless animals (the sloths, armadillos, ant-eaters, manises, &c.), eight in number, are equally distributed between the Americas and the rest of the world; the former, however, being richer in species in the proportion of 20 to 8. The sloths live entirely in trees, chiefly in the Brazilian forests; the armadillos range through Central and Southern America, as far as the 43d degree of S. lat. That rare and

most curiously formed little animal, the chlamyphorus, is found only in the provinces of Cuyòs, in Mendoza.—(*Sir W. Parish.*) The ant-eaters (myrmecophagi) extend no farther south than Bùenos Ayres (of which the largest is the M. jubatus, remarkable for his enormous mane). Among the Asiatic and Africa edentata, the manises, or scaly ant-eaters, have the widest range, being found in Senegal, North-east India, and the Eastern and Southern Asiatic isles. Australia possesses two genera, the echidna or porcupine ant-eater, and that most extraordinary animal, the ornithorhynchus paradoxus; the only mammal which lays an egg. It is found in the Murrumbidgi and other rivers in S.E. Australia.

(389.) Of the 39 species of pachydermata, arranged in 9 genera, none are Australian, one only (the wild boar) European. The elephant is limited to Southern Asia, Scythia, the Archipelago, and Central and Southern Africa; the hippopotamus is exclusively African; the rhinoceros conterminous, or nearly so, with the elephant. The swine and the horse (including the wild ass and zebra) are the most numerous in species of this class, nine species of the former being scattered over Europe and Asia, three (the wart-hogs) in Africa, and two (peccaries), being South American representatives of this family. The wild ass frequents the deserts and high plateaus of Asia, and the zebra is exclusively African. The tapirs have been already noticed.

(390.) The *carnivora* form a very large class, consisting of 514 species, arranged in 61 genera, and divided by strong natural characteristic distinctions, into five families, viz., the *digitigrades*, or those clawed beasts of prey, which spring and leap on their prey, and which comprehend, as *cats* (feles), the lion, tiger, leopard, panther, etc.; and as *dogs* (canes), the wolf, fox, etc., and which comprise the most active and formidable. The *plantigrades*, as bears, badgers, racoons, etc., which use the whole lower joint of the leg as their support, and (in the bear) stand often erect on it as a broad basis. The insectivorous (hedgehogs, moles, shrew-mice, etc.), a family little formidable: the *flying cats*, a small family confined to tropical Asia; and the *bats*. We find by far the majority of species, and, with exception of the bears and wolves, all the larger and most formidable ones, confined to the tropical countries. This is so marked, that, if we divide the world into austral, tropical, north temperate, and arctic (understanding by austral the extreme South America, from 40° S., with Australia and its connected islands), we shall find the *mean density* of species inhabiting each of these *seriatim*, to stand in proportion nearly as follows, viz.—

* This estimate is founded on the enumeration of species in particular districts, given in the *Physical Atlas*, and is so framed as to be, as far as possible, independent of overlapping.

Austral	8
Tropical	26
North Temperate	9
Arctic	7

The disproportion in the southern division would be still greater were it not for the comparatively large proportion of bats found in the Australian and Oceanic islands, the greater number of which, however, it should be observed, belong to the "frugiverous" bats, which only by courtesy of structure belong to the carnivora.

(391.) Among animals of this class a few only can here be specially noticed. The *lion* is found over all Africa, Egypt and the Libyan Desert excepted; and in Asia, only in the districts bordering on the Euphrates, in Persia, and the jungles of India. The *tiger* whose migrations, as we have seen, take a wide extratropical range, has its chief *habitat* in the forests and jungles of Bengal, the southern mainland of Asia, Java, and Sumatra. The *puma* ranges over both Americas, from 50° N. to 53° S.; the jaguar is principally found in Brazil and Paraguay. The wolf, though now nearly driven out of the more populous portions of Europe, is indigenous (with its American congeners) over the whole northern hemisphere, from the arctic latitudes down to the tropical ones. The bear is largest and most formidable within the arctic circle, as the white or polar bear, and in the North American forests, as the grisly bear of the Rocky Mountains and Western Savannahs. Within the tropics

their species are not numerous, and in the austral region none occur; neither is any species of the *insectivora* native in these regions, though otherwise pretty equally distributed over all the others. The *bats* are chiefly tropical, 55 species occurring in the tropical region of America, 41 in that of Africa, and 67 in that of Asia. Of these the only formidable one is the vampire, a West Indian and South American species, which sucks the blood of animals during sleep, and occasionally of man. The immense numbers of the bat tribe, which suspend themselves, head downwards, in caves in tropical regions; and, when disturbed, rush forth, rendering the darkness hideous with their ill-omened flappings; are always dwelt on with peculiar emphasis by those who have visited such scenes.

(392.) The *Rodentia*, though a very numerous class, will not detain us long. They consist of, 1. *Sciuridæ;* 2. *Muridæ;* 3. *Hystricidæ;* 4. *Leporidæ*, or animals allied to the *squirrel*, *mouse*, *porcupine*, and *hare*, divided as follows:—

	Genera.	Species.
Sciuridæ	14	169
Muridæ	47	306
Hystricidæ	30	99
Leporidæ	2	46
	93	620

Of these genera 44 belong exclusively to America, and 5 exclusively to Australia (the total number of Aus-

tralian species being only 21, and those confined entirely to the muridæ). Excluding these, the *mean density* of species in the temperate to that in the tropical regions of the globe is the ratio of 16 : 19.*

(393.) Among the rodentia the most remarkable are the beavers and the porcupines. The former (classed by a rather strained analogy among the squirrels) are represented in North America by the genus Castor, in Europe by Fiber. This latter form of beaver, within the *records of history*, inhabited Britain. Of the porcupines, 77 species belong to America, and only 6 to the Old World. The common porcupine is a native of south Europe: we remember to have picked up the quill of one, which seemed to have freshly dropped from the animal, in the immediate neighbourhood of Rome. The flying squirrels are natives of the Malayan peninsula and Java.

(394.) Of all the mammalia, and, indeed, of the whole animal creation, the *Ruminantia* are the most important to man. Of these there are 8 genera and 180 species, divided by Mr. Waterhouse as follows:—

	Species	Old World	New World
Camels . .	2	2	0
Llamas .	3	0	3
Musk Deer . .	7	7	0
Deer	51	37	14

* These numbers are concluded from Mr. Waterhouse's statement of the number of species in the *Physical Atlas*.

	Species.	Old World.	New World.
Giraffes	2	2	0
Antelopes	48	47	1
Goats	20	18	2
Sheep	27	25	2
Oxen	20	18	2

Of *camels*, the African and Asiatic (or Bactrian) are distinguished by having respectively one and two humps. Both inhabit arid regions, and are singularly provided with an additional stomach for the retention and conveyance of water in their long wanderings in dry places. The *llama* was the only beast of burthen known in Peru in the time of the Incas. It is the American representative of the camel, and has no hump. It is described as the "characteristic quadruped of Patagonia" by Mr. Darwin. Among *deer*, the rein-deer is by far the most important as an animal of wonderful endurance, speed, and docility—the special gift of Providence, as it would seem, to the inhabitants of the regions bordering on the arctic circle. The *camelopard* is exclusively African; and of its two species, the one belongs to North, the other to South Africa. The *antelope* also, though represented in Europe by the chamois, in America by the prongbuck, and in Asia by eleven other species, is yet, *par excellence*, an African animal, both in respect of the number of the species, and of the countless multitudes of individuals which, in their migrations in search of water, are described as covering the whole surface of extensive tracts of country like the waves of the sea.

Among the *goats*, the ibex frequents the loftier regions of the Swiss Alps. The Asiatic species frequent the Taurus mountains and Kamschatka. The *sheep*, domesticated in Europe, would appear to be traceable to Western Asia, where, as well as in Africa, the wild species frequent the more inaccessible mountain districts. Of the two American species, the argoli of the Rocky Mountains is remarkable for the enormous horns of the ram. Among *oxen*, the south African buffalo is wild and ferocious, the Indian domesticable. The American congener, the bison, exists in immense herds on the north-western American prairies, from California to 60° N., a huge, ugly, and terrible animal, the very type of blind brute force. It is in rapid process of extermination. The musk-ox is the only considerable ruminant of the arctic region of America. Australia produces no ruminant animal.

(395.) The *Cetacea* are a very peculiar class, numbering among them many forms which never leave the water, and have the external aspect and general attributes of fishes, as the whales, the cachalots, and the narwhals (balænæ, physeters, and delphinidæ), as well as the lamantin of the Orinoco, the dugong, and the porpoises, but they also comprehend two genera of animals, bearing little resemblance to fishes, and which are properly amphibious—the seal (phoca), and walrus or morse (tricheous), the latter of which is exclusively confined

to the polar seas, unless drifted southwards on floating ice. The former has a considerably wider range; sometimes reaching the Orkneys and Hebrides, and even the Isle of Wight, where, within our own recollection, a specimen has been captured in Freshwater Bay.

(396.) *Distribution of Birds.*—Six thousand species of birds are said to exist in the Museum of Berlin alone, but of those which are accurately described and classified and of which the *habitat* is satisfactorily known, the number is much smaller. Not much above half that number are enumerated as such by Mr. K. Johnston, and of these the mean densities of species in the several great divisions of the globe, concluded from the data of his enumerations, are, in proportion to each other, as follows, viz.:—

Europe	15
Asia	5
Africa	6
America	6
Australia and Oceanica	4

As regards the mean density of species, then, we see that, of these divisions, Europe far exceeds any of the others. As is the case with the mammalia, the mean density of species increases on approaching the equator. The distribution in zones of temperature, calculated on the same principle as before adopted, will give for the several zones the following proportions:—

Northern Frigid Zone	3
Northern Temperate do.	8
Northern Warm do.	5
Tropical do.	11
Southern Warm do.	6
Southern Cold do.	1

Where the abundance of European species is again apparent is the disproportionate percentage of the northern temperate zone, which here includes the whole of Europe. In this statistical view, the *habitat* of the migratory birds is assumed to be that in which they settle during their breeding season. Wide as the range would seem to be which the power of flight gives to birds, they appear to be retained to particular regions, independent of temperature, chiefly, no doubt, by the condition of their finding their appropriate insect and vegetable food; but partly also by local association of another kind, which seems to be strong in this class of animals; since we find instances of migratory birds identified as returning to the same spots for breeding in successive seasons.

(397.) The paucity of species in the arctic regions, both north and south, is compensated, especially in the former, by the multitude of individuals, which, mostly living on fish or other marine products, find there abundant food. Thus we find that even in so extreme a latitude as 80° 17′ N., at Cape Andrew Jackson, Dr. Kane reporting that "never had they seen the birds so numerous. The water was absolutely black with dove-

kies, and the rocks crowded" with these and with ivory gulls, molle-mokes, eider-ducks, brent-geese, etc. In 71° 56′ S., on Possession Island, in like manner we find the penguins assembled in countless multitudes, and fringing every ledge of rock.

(398.) Birds are divided into the orders of Rapaces (birds of prey), Scansores (climbers), Oscines (singing birds and perchers, including the humming birds), Gallinaceæ (poultry), Grallatores (waders and long-legged birds), and Natatores (swimmers). Of *rapacious* birds, the eagle is the noblest. The golden eagle inhabits the higher grounds of Central and Southern Europe, extending his range across the Crimea to the Caucasus, and being also a denizen of the Scotch and Scandinavian mountains. The condor, the largest of vultures (spanning 15 feet across the wings) soars far above the highest peaks of the South American Andes, but never crosses the isthmus to the northern range. The albatros disdains the land, and sleeps on the wing over the widest extratropical oceans, above which he seldom rises to any great height. Swanlike in apparent size, his wings extend 10 or 11 feet. The vulture of the old World is a native of Africa and India, and sometimes visits Sardinia.

(399.) Among the climbers, the most beautiful and interesting are the parrots, cockatoos, and lories. They are chiefly tropical, but in South America range to the extremity of the continent, and are abundant in Australia.

Birds of paradise are found exclusively in New Guinea and the neighbouring islands, with the Moluccas and Aroo islands. Toucans are confined to the tropical region of South America. The tropical region of Africa is poor in climbers, the species being to those in the corresponding region of America only as 21 to 122, or about as 1 to 6.

(400.) In the number and variety of its singing birds, Europe stands pre-eminent—110 species are especially so characterized; and the total number of birds of this order in Europe is 186. The nightingale (of which there are nine European species) sings, in England, nowhere north of the Tees and nowhere west of Exeter. Whatever the richness of European bird-song, however, North America can produce its single mockbird, the very embodied spirit of woodland melody (a native of Louisiana and Carolina), which, besides possessing an unrivalled song proper to itself, imitates in perfection, and even surpasses, that of every other species. The humming-birds also belong to this order. They are chiefly restricted to tropical America, but a few species range very widely. One has even been found on the shore of Behring's Straits, in 61° N., and others in Terra del Fuego, flying about in a snow-storm; so that, so far as climate goes, there is no reason why they should not be naturalized in Europe. In the Cape Colony they are represented by the "Sugar-birds."—(Certhia).

(401.) Of *Gallinaceous* birds, the peacock is a native of India; the pheasant is indigenous through Asia, from the Caucasus to Sumatra. That beautiful bird, the Argus pheasant, is a native of China, and the lyre-bird, the most elegant of the whole order, is the Australian representative of the pheasant family. The turkey, in its wild state, is peculiar to North-west America. The pigeon family is equally indigenous, both in the Old and New World, there being 6 European and 8 American species. They are found in countless myriads in the North American forests, where, in congregating to roost, they cover every tree, over large tracts, to crowding, and even break down great limbs by their weight, producing all the havoc of a storm. Flocks, consisting of millions, pass, twice in the year, over Canada and the northern states in their migrations north and southward. The dodo, a large gallinaceous bird of Madagascar, which has become extinct within the memory of man, is considered, from the structure of some of its bones, to have been a gigantic pigeon, too heavy for long flights, and thus, as in a similar case in the Isle of Rodriguez (that of the solitaire), to have fallen an easy prey to man.

(402.) The order *grallatores* or waders, besides storks, flamingoes, herons, etc., which really wade, is made to take in many long-legged birds which frequent the dry places of the earth, as the ostrich, the emu, the cassowary, etc.

The two-toed ostrich, the largest existing bird, is at present nearly confined to Africa, in the Old World, being, however, represented in South America by the three-toed ostrich Suri or Tuju (Rhea). Though unable to fly, its wings assist it in running, in which it is the fleetest of animals. In ancient times, its range extended through Asia Minor, Persia, and South Asia, to the farthest East, but it has become exterminated except in Arabia. The cassowary, which has hair for feathers, inhabits south-east Asia, and the Indian archipelago, as far as New Guinea. The emu (remarkable for its long, narrow double feathers) affords another instance of the singular bizarreries of Australian organization, as does also the Deinornis of New Zealand, which should it be (as is barely possible) not yet entirely extinct in the unknown interior of the Australian continent, must take the precedence of the ostrich as the giant of living birds, its skeleton standing 11 feet in height.

(403.) To the *swimming* birds belong the swan (which in Australia is black), the pelican, the eider-duck, and the penguin, besides innumerable geese, ducks, etc., which people the colder lakes and sea shores of Arctic Asia and of Northern America. Of 112 European species, 44 belong to this family, and 33 to the gulls. The pelican is a native of Eastern Europe, and is not uncommon on the Danube, and very common in Africa, in the tropical islands of Asia, at Siam, and in China. It occurs also,

very widely diffused, in North America, and even in South Australia, so that it is one of the most widely distributed of birds. The eider-duck is exclusively confined to the northern seas, though it has been known to breed as low as the coast of Northumberland. The penguin, on the other hand, haunts the desolate islands of the South Seas, the Straits of Magellan, and the Falkland Isles, and is unknown in the northern hemisphere.

(404.) *Distribution of Reptiles.*—Of the 1000 or 1500 species known to exist, those described and well ascertained as to *habitat* amount to 657, divided into families and genera as below, viz.—

Families.	Genera.	Species.
Testudines (tortoises)	3	69
Sauria (lizards)	9	203
Ophidia (serpents)	9	265
Batrachia (frogs)	5	120

And the proportions (in respect of the mean densities of species) in which these are distributed over the great divisions of the globe, and the zones of temperature are these, viz.—

Europe	3
Asia	5
Africa	5
America	8
Australia and Oceanica	3

And in zones, in the proportions (*inter se*) of the numbers:—

Temperate	11
Tropical	29
Austral	2

It is chiefly to the forests and swamps of Brazil and Guiana, which swarm with reptile life, that the marked disproportion between America and the other divisions of the globe is owing. The tortoises (including the turtles) are almost entirely tropical, very few land species existing anywhere beyond 30° or 40° of latitude, and the turtles frequenting only the tropical seas. The alligators or caymans occupy tropical America, frequenting the rivers from 30° south to 32° north. Of these, some species during the dry season bury themselves in mud, and remain encrusted and torpid till the first rains, when they at once start up, shake off their crust, and rush down to the first indication of a stream. Humboldt was, one rainy night, surprised by such a resurrection of one, over whose dormitory he had unknowingly made his own. The true crocodile is African and Syrian, and is found in the Nile and in all the rivers of tropical Africa, as well as the Euphrates. The gavial infests the Ganges. Chameleons abound in Africa, both north and south, and are even found occasionally in Spain and Italy. The iguana is eaten in the West Indies and in Central Africa (Livingstone), and considered very delicate food. Among the frogs, the most remarkable seem to be a species, called Matlametlo,

described by Dr. Livingtone as inhabiting the Kalahari district of South Africa; whose instincts, like that of the cayman above mentioned, excite him from torpor on the first symptom of rain, and one of which furnishes an excellent repast. In the case of the Surinam toad or pipal, the female hatches her eggs on her back, the young from which, when produced, bury themselves in her skin, and there undergo their transformations. This toad is 8 inches, and the bufo agua of Brazil 10 or 12 in length.

(405.) Of 265 known species of serpents, only 58 are venomous. The serpents of America are, without exception, *specifically* different from those of the Old World; and, in the latter, they are entirely absent in all the Pacific islands, while in those of the Indian archipelago they abound, though with singular and capricious exceptions. Thus in Java 56 species occur, in New Zealand not one; in Australia 10, 7 of which are venomous. Of 6 species found in Japan, none exist elsewhere. In no class of animated beings is the localization of species so marked. In general, however, in common with nearly all others, the abundance of species increases with proximity to the equator. Sea serpents, of which 7 species are known, all venomous, are found only in the Indian Ocean, and the seas of the Indian and Oceanic Archipelago. As regards particular and remarkable serpents, the rattle-snake (Crotalus horridus)

is North American, where it represents the European viper. The cobra-capello, or hooded snake (the dancing snake of the Indian jugglers) is common everywhere, from Malabar to Sumatra. The boas are peculiar to the tropical forests of South America; their representatives in the Old World, the pythons (one species of which attains 20 feet in length) range over North Africa, through tropical Asia, to China and Japan. This snake (which is not venomous) is probably that which gave rise to the extravagant exaggeration, in the accounts handed down to us, of Regulus's invasion of Africa. Lucan's description of the serpents which annoyed Cato's army is not less extravagant. Africa, in fact, as regards species, is not comparatively rich in serpents.

(406.) *Distribution of Fishes, Molluscs, and the Lower Aquatic Organisms.*—The *habitat* of Fishes, like that of land animals, is necessarily limited by the condition of their supply of appropriate food, as well as by that of an appropriate temperature, which for them is that of the surface water, since very few fishes are capable of sustaining the pressure of a greater depth of water than 100 or 150 fathoms, and in these the air-bladder is either entirely absent or in an imperfect or rudimentary state of development, such an apparatus being useless under the heavy pressure of 20 or 30 atmospheres. The way in which surface temperature may set a limit to the excursions of marine animals, even those of the

widest range, is curiously exemplified in the case of the whale. The "right whale" (Balæna mysticetus), according to Lieutenant Maury, is incapable of crossing the equator, and the whales of this class taken in the Southern Ocean are specifically different from those of the Arctic and North Seas. Yet, as we have seen (art. 49), the temperature of the tropical seas is superficial, and at a depth of two or three thousand feet would be so much mitigated, that but for the necessity of rising to the surface for air, which is common to all cetacea, there is no reason why he might not pass, since the whale habitually plunges down to immense depths, and seems quite unaffected by a pressure sufficient to "waterlog" the wood used in constructing whaling boats.

(407.) The ultimate food of such fishes as do not prey on one another is either the soft parts of marine vegetables, or such animal organisms of inferior orders as either draw their food from these, or extract it chemically from the water. Such are, of course, far more abundant, or at least more varied, in the neighbourhood of the shores, or upon shoals affording marine vegetation, or the estuaries of rivers bearing supplies from the land; and it is therefore to the vicinity of these that a very large portion of fishes is confined. The widest oceans, it is true, abound in organic life at and near their surfaces. Even in very cold latitudes countless millions of creatures of the genus Beroë exist, and others of a

larger size, medusæ (or jelly fish), zoophites, etc., swarm to such an extent, as to convert the surface water in some places almost into a kind of soup, which furnishes food not merely to small fish but to cetaceæ of the largest growth; and in tropical regions the sea teems with minute forms of animal life in infinite variety—small mollusca, crustacea, and luminous creatures, as salpæ, pyrosomas, etc., many of them gelatinous; and where the sea is covered with floating weeds, these become the haunts of a numerous population of species, crabs, sea-slugs, etc., peculiar to them. Thus, whatever be the distance from shore, food is not wanting for such fish as are fitted for its assimilation, and the fish of prey (as is also the case with land animals) are confined by no limits but those which temperature sets to their range.

(408.) The cetacea are not properly fishes, but belong to the class of mammalia; and inasmuch as many of them breathe air, and are obliged to come to the surface for its renewal, border on, and, in the cases of the seals and walrus, really are *amphibia*; in those of the lamantin and dugong, nearly such (art. 395). The larger whales, as a family, have a very wide range, and some of the species are found in almost every sea. The Balæna mysticetus, as we have seen, does not appear between the tropics, nor does the narwhal, which is specially arctic. The Rorqual (which furnishes whale

bone, and is said to attain 100 feet in length) is a denizen of high latitudes (70°—80° N.) The Cachalot (Physeter macrocephalus), on the other hand, does not visit the colder seas, but wanders over the whole of the temperate and torrid ocean, affecting always the central and deepest parts. The grampus, porpoise, and dolphin occur in almost every sea.

(409.) Among fishes of prey, the sharks, though not confined to the tropical seas, are there by far most abundant. Some occasionally visit our own seas. The largest of the family (Squalus maximus), the Basking Shark, visits pretty high latitudes. It has been seen off the north-west coast of Scotland, where it has been taken for the "sea serpent." It attains 50 or even 60 feet in length, and one of the former size was lately taken at Kuraci, at the mouth of the Indus. Happily its voracity is not in proportion to its size, as it lives chiefly on medusæ and sea-slugs, small fishes, etc.

(410.) The localization of those fish which live near the shore, and furnish the principal part of the marine contribution to human food, is often very limited, and we find almost as many littoral "provinces" of fish as there are lines of coast characterized by some common feature either of soil, rivers, or climate. In general, it may be noted as a universal feature, that the colder waters furnish those species best fitted for food, and that even in the same species the individuals taken in cold

waters are far superior in flavour and nutritious quality to those in warmer seas. According to Lieutenant Maury, the excellent fish with which the Atlantic cities of the United States are supplied, owe all their value to the stream of cold water which sets down the coast out of Baffin's and Hudson's Bay, between it and the Gulf Stream (art. 55). "The 'Sheep's-head' (? species), so much esteemed in Virginia and the Carolinas, when taken on the warm coral banks of the Bahamas, loses all its flavour, and is held in no esteem. The same is the case with other fish. When taken in the cold water of *that coast they have a delicious flavour*, and are highly esteemed; but when taken in the warm water on the other edge of the Gulf Stream, though but a few miles distant, their flesh is soft, and unfit for table." "A current of cold water from the south sweeps the shores of Chili, Peru, and Columbia, and reaches the Gallapagos Islands under the line" (art. 64). "Throughout this whole distance the world does not afford a more abundant or more excellent supply of fish. Yet, out in the Pacific, at the Society Islands, where coral abounds and the water presents a higher temperature, the fish, though they vie in gorgeousness of colouring with the birds, plants, and insects of the tropics, are held in no esteem as an article of food. I have known sailors, even after long voyages, still prefer their salt beef and pork to a mess of fish taken there." (*Phys. Geog. of the Sea*, p. 55.)

(411.) The phenomenon of coloration referred to in the last sentences of the above extract is a general one. The arctic and northern fishes have little colour, and as the zones of temperature ascend in the scale towards the equator, the species, not only of fishes, but of all marine animals in all seas, become more highly and more variously coloured. The brilliancy of colour of the fishes, shells, and sea-weeds of tropical, and especially of the Indian and the Caribbean Seas, is spoken of with admiration by every voyager, and is enhanced by the purity of the water in those bays and recesses which are kept clean and scoured by the indraft of currents from the deep ocean.

(412.) A bare enumeration of the several "littoral provinces" of marine life (and our limits would allow little more) would be of small interest, and it will suffice to observe that, with exception of arctic forms, which have a common origin in the polar seas, and are, therefore, propagated downwards in both oceans, scarcely any forms of littoral marine life are specifically identical in the Atlantic and the Pacific, and that even on opposite sides of the Atlantic itself but few species are common to both.

(413.) Of migratory fish, some resort to rivers to spawn. The principal of these is the salmon, which is found in most of the rivers of cool temperate coasts down to the 45th degree of latitude; and so definite are

the habits of the fish in this respect, that in adjacent rivers, on the N.W. coast of Ireland, abounding in salmon, the fish of each river are known to the fishers by some peculiarity sufficient to ground a recognized claim on the part of one proprietor to fish accidentally straying into the precincts of another. On the other hand, such fish as migrate seaward, as the cod, the herring, and the pilchard, appear to be driven southward by the cold of winter, or by the failure of their food resulting from it, and descend in immense shoals, and at fixed periods, like the birds. Thus the cod arrives annually on the banks of Newfoundland, along the cold current inside the Gulf Stream, and also in the North Sea, descending by the coast of Norway, in February, to the Dogger Bank in shoals so dense that the sounding line can hardly pass between them. The herring also visits our coasts in winter, its migrations being very definitely limited to water of a certain precise temperature, a circumstance which, taken in conjunction with the fluctuations known to exist from year to year in the limits of the Gulf Stream, and the surface-drift currents from the S.W. (art. 55), may serve to explain the seemingly capricious desertion of certain bays and haunts of these fish in some years, and their appearance in others not previously frequented by them.

(414.) About 853 species of European fishes have been described, of which 643 are marine, 210 live

entirely in fresh water, and 60 of the marine species resort to fresh water to spawn. Of the marine species 444 inhabit the Mediterranean, 216 are found off the British coasts, and 171 are peculiar to the Scandinavian seas.

(415.) It would be wrong, in speaking of fish, to omit all mention of that remarkable and very curious power manifested only in this class of animated beings —the power of giving forth a voluntary electric shock. This is possessed by several distinct species: among sea-fish, by the torpedos, four species of which are found in the Mediterranean, and others in the Indian seas. They occur also in Table Bay at the Cape of Good Hope. The Isle de Rhe, on the French coast, is remarkable for the frequency of the occurrence of one species. The Gymnotus electricus, whose shocks are most formidable and even dangerous, is a species of eel which inhabits the Orinoco, but is more common in pools and marshes on the eastern bank of that river. It is also found in other rivers of the eastern part of South America; and Humboldt calculates that each square league of the Planos de Caracas contains two or three ponds filled with these creatures. It is caught also in Guiana.

(416.) The distribution of the marine mollusca and other animals of the invertebrate classes is very powerfully influenced by the element of vertical depth. In

that of vegetable life we have seen how increase of altitude in the air acts with all the influence of increased latitude, as bringing the plant into a colder region; but the influence of depth in marine life is one of a quite different kind. As regards temperature, no doubt the water in the shallow sea-bords is subject to diurnal and annual fluctuations of temperature to a considerable extent, though much less than the air, and this affords a condition of existence which cannot but be very influential in determining the species which can exist at the extreme borders of the sea. But the amount of this fluctuation diminishes very rapidly with the depth. Not so, however, another very important element of all life, viz., light. The light which penetrates to great depths is not merely much less in quantity, but very different in its photo-chemical qualities, from the entire solar light of the surface, and this, though at present we are ignorant of the mode and laws of its agency on the animal economy, we are very sure is an element of exceeding importance. The food, etc., afforded by submarine vegetation is different—the texture and constitution also of the sea-bed, as consisting of finer particles carried out far to sea, affects its quality as a nidus for habitation, so that we find the zones of habitable depth in the water to succeed one another with far greater rapidity, and to be confined within far narrower limits than those of atmospheric altitude on land.

(417.) Professor E. Forbes, to whose researches we owe a very large portion of our knowledge of this part of natural history, has discriminated the zones of depth affected by marine animals into, 1*st* Littoral, between high and low water-marks—a zone which might *à priori*, be expected to be very strongly characterised, as we find it to be, by species capable either of maintaining an active existence in air as well as water, such as crustaceous animals, crabs, etc., of various families, or of such testacea and shell-less animals as close themselves up, or seal themselves hermetically on the rocks, and remain dormant during the recess of the water, of which the patellas, mytili, littorinas, purpuras, etc., and, among the zoophytes, the common sea anemone, afford examples: 2*d*. The "circumlittoral zone," with a depth from low-water mark to about 15 fathoms. 3*d*. The "median zone," from 15 to 50 fathoms. 4*th*. The "infra-median;" and 5*th*. The "abyssal zone," the former from 50 to 100 fathoms, the latter from thence to the lowest depth at which life is possible, which in some of the minuter forms* would seem to include almost the lowest deeps that the sounding line has reached (see art. 118). Each of these zones is characterised by species which belong to no other, and each passes into the other by the inter-

* [And not in those alone. A star-fish upwards of 5 inches in diameter has been lately brought up living from a depth of 1260 fathoms by Dr. Wallich at the mouth of Baffin's Bay.]

mixture of species common to several. It would carry us quite beyond our limits to enumerate these, and without specific detail the mere enumeration would afford no instruction. Suffice it to observe, that in these, as in other departments, proximity to the tropics carries with it increase in the number and variety of species and genera, greater development in size, form, and colour. The shells of the Indian Seas, and the Eastern Archipelago in particular, are prized not merely by the zoologist as illustrative of animal organization, but by collectors for their exceeding beauty, brilliancy of colour, and elegance of form. It is in these seas also that the pearl-fisheries are conducted, the true pearl oyster being confined to them, though pearls of inferior quality are produced also by a certain species of mytilus: and Suetonius has recorded that Cæsar's first idea of invading Britain arose from the report of pearls being found on its coast (*Britanniam petiisse spe margaritarum*). The depth, moreover, has quite as marked influence on the colour of shells as the warmth of the water on the flavour of fish. Below the level, where light can penetrate copiously, the colour of shells wax faint and dilute, and even individuals of the same species taken at different depths exhibit a marked difference in their intensity of colour. The circumlittoral zone, it may be generally observed, is that of the reef-building corals (art. 87), of star-fishes, sea-urchins (Echini), and cuttle-fishes—the

medial of sponges, corralines—the infra-medial of the deep-sea corals—and in particular, of the valued red corals of the Mediterranean. As respects all the zones, also, it is remarked by Professor Forbes, that as we descend, the regions of depth characterised by the same species become of greater extent, *and the range of species (in a horizontal direction) wider.*

(418.) *Distribution of Insects.*—All nature seems to swarm with insect life; but here, as in all departments of natural history, we find fewer species inhabiting the colder regions; and their maximum of development, both in variety, richness of ornament, and what may be termed *intensity of quality*, is found in the hottest countries. There it is that the greatest singularity of form and habit, the greatest pungency of bite, and every other mode of insect annoyance, are found in perfection. The only exception seems to be in the case of coleopterous insects, which are specifically more abundant in temperate climates.

(419.) According to Mrs. Somerville, the rate of increase of insect life, in proceeding from either pole to the equator, is very various in different longitudes. Their numbers are small in both the polar regions—more abundant in Tasmania and New South Wales—more so in Southern and Western Africa, Columbia, and a maximum in Brazil; but North America has fewer species than Europe in the same latitude; and

Asia is comparatively poor in species, in proportion to its great extent. The horrors of insect annoyance in the swamps of the great rivers of tropical America are vividly described by Humboldt. The air is one dense cloud of poisonous insects to the height of 20 feet. In Brazil the vivid colours and metallic brilliancy of many of the beetles is extraordinary. Among the more remarkable varieties of insect life deserve special mention, *1st*, the bees and ants. Of the former each country has peculiar species; but it is singular that the honey bee of North America has been introduced from Europe.* The ants, of which the species are almost innumerable, are found chiefly in hot and dry climates, and are, perhaps, of all insects the most remarkable in their habits. The termite of tropical Africa builds pyramidal nests ten or twelve feet in height, hollowed into chambers of elaborate structure. The white ant of India devours everything of animal and vegetable origin, ascending by covered galleries (for they cannot bear the light) to the sap of furniture, beams, etc. But perhaps the most singular species of all is that of the parasol ants of Trinidad, in the West Indies, which walk in long procession, each carrying a cut leaf over its head, as a parasol, in the sun, and these they deposit in holes 10

* We take this fact on the report of Mrs. Somerville (*Phys. Geog.* p. 397), but is there not some mistake? At all events, the search for wild honey has, from the earliest settlement, been a feature of American forest life, but the indigenous species is, perhaps, undomesticable.

or 12 feet deep under ground, apparently with no other object than to form a comfortable nest for a species of white snake, which is invariably found coiled up among them on digging out the deposit (Mrs. Carmichael's *Domestic Manners, etc. etc. in the West Indies*, ii. 327). The scorpion extends in Europe to the north coasts of the Mediterranean, but is more abundant in Africa, both north and south, where its bite has the singular peculiarity, that, although excessively painful on the first occasion of its infliction, and even dangerous to life, the constitution becomes hardened to it, the suffering is less on every subsequent occasion, and at length comes to be little regarded. Brazil produces a scorpion six inches in length. The locust, one of the most formidable scourges in countries infested by it, migrates in such masses as to darken the air for successive days, and when driven into the sea is sometimes thrown up as banks on the shore, poisoning the air by their decomposition for many miles in length. They are frequent in Syria and Barbary, whence they occasionally migrate to Italy, and within this last summer (1858) several individuals have even been taken in England, and one or two in London. They are even said to cross the Mozambique Channel from the African coast to Madagascar.

Fossil Organic Remains.

(420.) Buried in the strata of which the earth's crust is composed, we find in every part of the world, and in all the strata properly so called (excluding thereby granitic and other igneous formations, and the metamorphic rocks in which the evidences of stratification appear to be obliterated by partial fusion, or softening at least, by heat), either the actual harder exuviæ, such as shells, bones, scales, etc., or impressions of the softer and more destructible parts of animals, and the remains of vegetables silicified or otherwise fossilized, affording evidence of the abundant existence of organic life in every stage of the world's history. It is only in the newest and most superficial strata, however, that we find imbedded the remains of any species, either animal or vegetable, now existing in a living state, and these consist almost exclusively of the shells of marine and some freshwater mollusca. As we go deeper in the order of stratification, existing species rapidly become rarer, existing genera thin out and we find ourselves very soon landed in an order of things where the Fauna and Flora have nothing in common with the present, or rather in a succession of such (art. 11).

(421.) The strata in which we find this gradually decreasing community of organic life with that now in existence, are those which lie wholly above the chalk for-

mations, and which have been termed by Sir. C. Lyell, Tertiary, drawing the line between these and the secondary deposits at this point; and they have been subdivided by him into three stages or epochs, the Pleiocene, or that *more* nearly approximating (πλειων) to the present *new* state (καινος); the Meiocene, or that *less* recent (μειων), or in which the number of species, common to them with the present epoch is less; and *Eocene* (ηως), that in which, as it were, only a *dawning* of the present state is visible. The upper of these three has been subdivided into *older* and *newer* pleiocene or pleistocene, that which approaches nearest, by the abundance of fossilized species identical with living ones, to the modern state. Now in these, if we reckon only the fossil shells as compared with those recent, we find, according to Sir C. Lyell, in the newest or pleistocene strata, nearly 96 per cent of recent, and only about 4 per cent of extinct species; in the older Pleiocene, the recent species still predominate, varying from 50 to 66 per cent of the whole number, while in the Meiocene, the proportion falls already as low as 18 per cent, and in the Eocene, does not exceed 3½.

(422.) In the strata forming under our eyes, in estuaries, lakes, and shoal deposits, of course the remains of all existing animals and vegetables become imbedded; but already in the Pleistocene strata an immense majority of the existing mammalia and birds has disappeared, and those few species which can be identified with now

existing ones are confined mainly to the *very newest* of these formations, designated by some geologists as Post-pleistocene, or in "Bone-caverns" in some of the older formations still open to day, and which have served as dens for carnivora, or places of refuge for other animals during all that period which may have elapsed since those formations were raised above the ocean. It is in the Pleistocene and these Post-pleistocene beds that we find the remains of a few terrestrial animals which have *become* extinct during the present geological epoch, and which either certainly have, or may reasonably be presumed to have, been contemporary with man, such as the Dodo, and the Solitaire (art. 401), the Deinornis of New Zealand (art. 402), six species of which have been discovered, and Opyornis of Madagascar, second only to the Deinornis in size, whose *egg-shell* has been found equal in bulk to six of that of the Ostrich, and which has only recently become extinct. Such also are those remains of gigantic elephants (art. 220) preserved in ice in Siberia, the Mastodon of North America, so slightly covered as to have been known to the aborigines, and to have given rise to obviously fabulous and mythological traditions of its contemporary existence,* those gigantic Sloths of the Pampas of Brazil (art. 238) and the fossil

* At Bigbone Lick, in northern Kentucky, the *contents of the stomach* of the Mastadon Giganteus have been found, consisting of crushed branches, leaves, and a species of reed now well known in Virginia (Delabeche).

Elks (Cervus Megaceros) of the Irish peat mosses, which are found in soft muddy deposits just below the peat, where they would seem to have perished by becoming embogged, a group of eleven of their skeletons having on one occasion been discovered in a standing position, and without signs of violence.

(423.) If we take in the whole range of the tertiary formations, we embrace nearly the total extent in time of the full development of Mammalian existence, as well as that of birds, though the latter would seem (as might indeed be expected from their power of migration and readier escape from destructive events, to take a somewhat wider range through past time than the others. In the cretaceous strata we find no mammals, and only a few indistinct vestiges of one or two genera of birds. Below the chalk in the Oolitic beds (art. 387) only two or three genera of Marsupial animals have been detected, and the footprints of birds even as low as the Permian series; while, on the other hand, we find in the Eocene formations, enumerated by Prof. E. Forbes, 25 genera of mammals and 8 of birds; in the Meiocene and Pleiocene, 81 genera of mammals, and many birds of existing genera, and in the Pleistocene and Post-pleistocene, no less than 88 extinct mammal generic forms, besides those still existing, and among the birds, many of the now existing *species*.

(424.) The distribution of these extinct forms over

the globe affords matter of highly interesting and important remark. A marked and almost complete separation subsists between the fossil Faunas of the Old World, America, and Australia; while, on the other hand, subject to that condition, the range of genera and species within those limits appears to have been much wider than it is at present. And what is still more striking is the fact, that the types which, in their several divisions, are more especially characteristic of them in the recent epoch, or what is equally so, the absence of particular types, are found no less to prevail *in the fossil Faunas.* Thus Australia is especially characterized (art. 387) by the exclusive prevalence of the marsupial type, which is altogether absent in other parts of the Old World, and represented only by a single genus in the New. And in its fossil Fauna we find an equally striking prevalence of the same singularity. According to Professor Owen, whose views in this and the following articles we adopt from the striking address pronounced by him from the chair of the British association at Leeds, on the formations of the most recent tertiary periods, and in the limestone caverns of Australia, abundance of mammalian fossils have been found, but *except a single tooth of a mastodon,* all of marsupials. Among them are fossil kangaroos, potoroos, wombats, dasyuri, etc., equalling the lion and leopard in size, a wombat (phaseolomys gigas) equalling the tapir, and

others of peculiar characters, rivalling the ox and rhinoceros in bulk. The skull of one of these great marsupials (the nototherium) from the "Darling Downs," presents the strangest peculiarities hitherto seen among mammalia; and that of the diprotodon, from the same locality (remarkable for two large and strong tusks projecting horizontally, straight forward from the lower jaw), is hardly less extraordinary. On the other hand Europe, Asia, and Africa have not offered a single marsupial fossil in the pleiocene and pleistocene deposits, and those in America are limited to the genus didelphis (opossum), species of which at present exist there. In the meiocene and eocene deposits, however, didelphidæ are found both in France and England (from which it would seem reasonable enough to conclude that in those periods a land communication existed between the continents).

(425.) The distinction between the fossil Faunas of America and the Old Continent is not less marked. "All the fossil remains of quadrumana in the Old World belong to the family (Catarhina), which is still exclusively confined to that great division of dry land;" but the quadrumanous fossils of the New World exhibit exclusively platyrhine forms—those, *i.e.*, of a family peculiar to South America, among which is one larger than any now known to exist, found in Brazil.

(426.) So again of the camels. The camel and drome-

dary, the two European genera of that family, are represented in America by genera (the llamas and vicugnas) characteristically distinct. And the fossil camels of Asia are referable to the same type (camelus) as those there now existing, while those of America belong to the llama type (auchenia).

(427.) The giraffe and hippopotamus are at present African. Fossil remains referable to these familias are, however, found in the pleiocene strata, both of Asia and Europe, but none have been met with in the New World; neither has any form of rhinoceros been discovered in its strata, though Europe, which is now deprived of that form, anciently possessed several species, one destitute of the nasal horn, and three provided with two of those weapons, one of these being fur-clad, adapting him for a cold climate.

(428.) As regards the elephant family, the case is somewhat different. This family, according to Professor Owen, has been more "cosmopolitan" than any other hoofed herbivorous quadruped. Yet even here the distinction between the Old and New World type is by no means obliterated. Especially corresponding to the representative of the elephant in America is the mastodon. Of elephants we have *now* an African and an Asiatic species, and no American. But while we find in a fossil state one North and two South American mastodons, and one elephant at least, it appears that

double that number of species, both of elephant and mastodon, all specifically distinct from each other and from the American, inhabited Europe during the pleiocene epoch. Of these elephants, the largest ever found, which appears, by the only remaining bone, to have been of at least twice the *linear* dimensions of the large mastodon exhibited in the British Museum, was found in making a railway cutting, in the Valley of the Thames, at Grays, in Essex, through the upper pleiocene. The skeleton, when found, was nearly complete, but was *broken up* by the workmen, and sold as bone manure to a neighbouring farmer, one only metatarsal bone finding its way to our national collection! In further illustration of this wider range of the elephant family in past epochs, Professor Owen observes, that not only China (in which at present there are no elephants), but even Australia (witness that single tooth before alluded to), has furnished evidence of the fact.

(429.) The distribution of fossils of the class of edentata furnishes additional evidence of the same laws. The manis or pangolin of Asia and Africa corresponds in South America to the ant-eaters; and at present neither does the one form exist in Europe nor the other in North America. In the European tertiary beds, however, a large pangolin has been discovered, while the domain of the armadillos and sloths, as well as the ant-eaters, in the same geological epochs, is now ascertained

to have extended over North as well as South America, though still confined to that continent. Their present peculiar *habitat*, however, Brazil; and the neighbouring regions of South America, were then, as now, the head-quarters of the family, the sloths being represented by the gigantic genera of megatherium, megalonyx, mylodon, etc., (of which the megalonyx, an animal as large as the rhinoceros, ranged at least as far north as Virginia), and the armadillos by the glyptodon, hoplophorous, pachytherium, chlamydotherium, etc. The mylodon, an animal of the most enormous strength, and which probably lived by uprooting large trees and feeding on their branches, though found near Buenos Ayres, was probably floated down by the Parana or Uraguay; but the glyptodon, which was discovered by the horse of a gaucho striking his hoof through its huge carapace (Parish, *Buenos Ayres*, etc., 222), must have lived and died on the spot during the recent epoch.

(430.) One of the most remarkable features of the Mammalian fauna and birds of the tertiary world is the gigantic size attained by many of the species. Several instances of this have been noticed in the preceding articles, and many more might be added; in particular, the Deinotherium, the largest of terrestrial mammals, a creature 18 feet long, with two enormous tusks curving downwards from the extremity of the *lower* jaw. This animal has been of wide distribution, during the Meio-

cene period, having been found in strata of that age at Eppelsheim, in Hesse-Darmstadt, in France, Switzerland, and the Sivalik Hills in India; several reasons exist why, supposing all the species of a genus to have been at one time coeval, and to have ranged to the utmost extent to which the then existing impassable barriers restricted them, the larger species should have died out first, and the limits of the genus (especially it of non-migratory habits) have become restricted. "In proportion to its bulk," observes Prof. Owen, "is the difficulty of the contest which, as an organized whole, the individual of such species has to maintan against the surrounding agencies, which are ever tending to dissolve the vital bond, and subjugate the living matter to the ordinary chemical and physical forces. Any changes, therefore, in such external agencies as a species may have been originally adapted to exist in, will militate against that existence in a degree proportioned, perhaps, in a geometrical ratio, to the bulk of the species. If a dry season be gradually prolonged, the large mammal will suffer from the drought sooner than the small one; if such alterations of climate affect the quantity of vegetable food, the bulky Herbivoræ will first feel the effects of stinted nourishment. If new enemies be introduced, the larger and conspicuous quadruped" (and we may state the more helpless birds, if provided with none or only rudimentary wings) "will fall a prey, while the

smaller will conceal themselves and escape; smaller animals are also usually more prolific than larger ones. The actual presence, then, of small species of animals in countries where larger species of the same natural families formerly existed, is not the consequence of any gradual diminution of size of such species. . . . . . The smaller and feebler animals have bent and accommodated themselves to changes, which have destroyed the larger species."—*Zool. Trans.* iv., p. 15.

(431.) *Bone Caves and Osseous Breccias.*—The caves noticed in art. 420 exist in great abundance over most parts of the world in which limestone, of whatever age, abounds (art. 197), and they are peculiarly important in respect of this inquiry, by reason of the vast abundance and variety of fossil remains they contain of animals, which we may be assured inhabited the surface while they were open and accessible. The most remarkable of such caves in Britain, are the Kirkdale cave in Yorkshire, examined by the late Dr. Buckland, Kent's Hole near Torquay, the cave of Paviland or Goat's Hole near Swansea, and that of Yealm Bridge near Plymouth. In Belgium such caverns occur at Chockier near Liège. In France we find the Grotte de Fouvent, and the caverns of Miallet near Anduze (dep. du Gard) in dolomite, that of Bize (dep. de l'Aude), those near Lunel-viel (dep. du Herault), and the Grotte d'Osselles near Besançon. In Germany a tract of country nearly 200 miles in extent

has been pointed out by Cuvier as full of such caves, and those of Gaylenreuth are particularly celebrated for the number of extinct bears, hyænas, etc., they have yielded, and for the singularly inaccessible situation (at present) of some of them. In Sicily several bone caverns have been examined within a few miles of Palermo. But perhaps those that have yielded the most striking results are the Brazilian bone caverns examined by Mr. Lund, and others which have been found full of those strange and wonderful forms which especially characterize the South American fossil fauna, large Amadillos, Glyptodons, Megatheria, Scalidotheria (nearly equalling the rhinoceros in bulk), etc.; and those in Wellington Valley, 200 miles N.W. from Sydney in Australia, where were found the principal among those extinct marsupials above mentioned.

(432.) In these bone caves, not unfrequently two or three layers of bones, separated from each other by stalactitic floorings, are found; and when this is the case, the upper usually contains remains of living, or *very* recently extinct species, and not seldom human skeletons. But wherever this has been the case, there has also been reason to conclude, from circumstantial evidence, that the caves have been used as places of sepulture or of refuge; and though, in many instances, such remains are doubtless of great antiquity (using the term as referring to human history), there has never

been discovered any fossil human bone so embedded in even the most recent geological *stratum*, other than the merest superficial alluvium, as to afford the slightest ground for believing the earth to have been inhabited by man during the epoch of its formation. On penetrating through the stalactite beneath the first loose layer of bones, the species found in the lower beds are usually found to belong to genera of earlier epochs.

(433.) Not less remarkable than the accummulation of bones in caverns, is the frequent occurrence in all parts of the world of osseous breccias, or beds of bones either reduced to fragments or entire, cemented together by calcareous stalactite. Such are found in great abundance all along the north coast of the Mediterranean—at Gibraltar, Montpellier, Nice, etc. Some of the Greek isles, too, as Cerigo, abound in such breccias, the bones from the latter being crushed and comminuted in the most extraordinary manner. To any one who reflects on the destructive effects of sudden inundations, in sweeping away and drifting together the drowned carcasses of tens or hundreds of thousands of animals (as recorded in the floods of the South American rivers), the causes of such accumulations will offer no difficulty.

(434.) Among the Mammals of the earliest tertiary or eocene period, the most remarkable are those discovered by Cuvier in the Lacustrine formations of the Paris basin, and especially in the gypsum quarries of

Montmartre, scarcely a block taken from which does not disclose some fragment of a fossil skeleton. Here, among extinct species of extinct genera, we find the Palæotherium, Anoplotherium, Cheropotamus and Adapis, and among extinct species of genera still existing, bats, wolves, racoons, genettes, dormice, squirrels, and several birds, besides a small didelphis allied to the American opossum. The Deinotherium belonged to the Meiocene, and the Machairodon to that and the Pleiocene, the latter being a genus of very wide distribution, species of it having been found at Buenos Ayres, in Britain, in France, in Germany, and in the Sivalik hills in India.

(435.) Among the fossils of the tertiary epochs, occur many reptiles, the most remarkable of which is the gigantic tortoise discovered in India by Messrs. Falconer and Cautley, the colossochelys; but the greatest development of reptile life appears to have taken place during the deposition of the secondary strata. Thus, we find enumerated by Professor E. Forbes, in the Cretaceous formations, 8 genera of reptiles; in the Oolitic and Wealden, including the Lias, 24; and in the Triassic beds, 16. They extend, indeed, somewhat lower in the scale, as in the Permian members of the upper Palæozoic rocks four genera are enumerated; and even below the coal, in the Devonian strata, two genera are found among these animals. The most remarkable forms are those ot

the Saurian family, most of them aquatic lizards furnished with paddles in lieu of legs, and many of them marine (Enaliosauria). Among them occur several of gigantic dimensions or monstrous form, as the Mososaurus of the upper chalk, near Maestricht, a species allied to the monitor, 25 feet in length; the Hylæosaurus, of equal dimensions; the Ichthyosaurus and Plesiosaurus of the Oolite and Lias, and others. In the Stonesfield slate occurs the Megalosaurus an amphibious or land lizard, carnivorous like the crocodile, and from 40 to 50 feet in length; in the newer Oolite or Wealden, the still more gigantic but herbivorous iguanodon, which, according to Dr. Mantell, attained 70 feet. In the strata below the Lias, in the upper red sandstone, we find that extraordinary gigantic Batrachian, the Labyrinthodon, and the Cheirotherium, whose footmarks only have been discovered. But the most singular reptile form of the whole series is that of the Pterodactyl or flying lizard, with bat's wings and crocodile jaws, furnished with 60 pointed teeth, which first appeared in the epoch of the Lias, and became extinct in that of the chalk, and of which several species have been found.

(436.) Comparatively few fossil serpents have been discovered, and those only in the tertiary formations—the Eocene deposits of England have afforded some of the largest, forming two genera, Palæophis and Paleryx —the largest of which was equal in size to the largest

boa constrictor of the present day. Some small snakes have been found in the Meiocene and Pleiocene formations of France.

(437.) Among the fishes, no existing genus is found below the chalk. In the inferior chalk there is one living genus, Fistularia; in the true chalk, 5; in the tertiary strata of Monte Bolca, 39 living and 38 extinct, according to M. Agassiz, to whom we owe a system of classification of this order of vertebrata by their scales, a character peculiarly adapted to fossil fish, of which frequently only the scales and a few of the harder bones remain, according to which they are divided into four great groups, Placoid, Ganoid, Ctenoid, and Cycloid. Of these four great families, the two latter are found only in the cretaceous and tertiary strata, and not a single species is of older date. In the cretaceous strata, they occur mixed with species of the two former classes. The epoch when the chalk began to be deposited forms therefore a very decided break in the history of this class of animals. And again, of the two more ancient orders, the Palæozoic rocks contain almost exclusively the remains of that class of fishes known as heterocercal, in which the upper lobe of the caudal fin is much more developed than the lower; while the secondary rocks contain the homocercal, in which the lobes are equal. The most remarkable deposits of fossil fishes are those of the Monte Bolca limestone

near Verona—the coal formation of Saarbrück in Lorraine, the bituminous shale of Mansfield in Thuringia, —the blue slate of Glaris, and the marl stones of Oëningen in Switzerland, and of Aix in Provence, and our own old red sandstone. The distribution of genera, according to Professor E. Forbes, is as follows:—Newer Tertiary, 40 genera; Older Tertiary, 38; Cretaceous, 61; Oolitic, 61; Triassic, 15; Permian, 14; Carboniferous, 31; Devonian, 43; and Silurian, 2. (?)

(438.) The mollusca, from the durability of their shells, have left behind them almost a complete record of the ancient zoology of this class of animals. Their remains furnish the chief and most available practical means of determining the relative ages and order of superposition of strata, and are thus the main stay of geological science. As such, then, their study assumes a technical aspect, and can only be followed up in professedly geological works (see the article on that subject in the Encyclopædia Britannica, and every geological treatise of note). The same evidence is afforded of the continual introduction of new genera and species, and dying out of old, as in every branch of zoology, the range, however, being far wider than in any before treated of. In fact, these, and the forms of radiata and articulated animals and of zoophytes, occur as the first vestiges of animated existence in the earliest fossiliferous strata. As might be expected, from the

greater probable uniformity of condition afforded in marine over terrestrial life, the families have been much more persistent than those of the higher organisms. Thus the lingula, a brachiopodous genus of the very earliest silurian epoch, has its generic representatives still living. The nautilus, a cephalopod of the older palæozoic series, has still its place among living genera. We have also natica, eulima, solarium, and capulus among the gasteropods, and cardium, mytilus, arca, isocardia, avicula, and terebratula, among the acephalous molluscs; while, on the other hand, some of the genera of earliest appearance (as orthoceras, cyrtoceras, phragmoceras, gomphoceras, and lituites) died out before the commencement of the secondary period. The ammonites, a most extensive and characteristic genus of the secondary period, in like manner died out before its close, as was also the case with the belemnitic, scaphytic, and turrilitic forms. This is the more remarkable in the case of the ammonites, as there is scarcely any generic form of organized life which seems to have luxuriated into so vast a variety of species. Bivalves are rare in the older formations.

(430.) Among the articulata, the trilobite, a form long since extinct, is highly characteristic of the earliest formations. They extend up to the carboniferous epoch. Crustaceous animals gradually approaching recent forms commence from the oolitic and cretaceous epoch. In-

sects are of comparatively rare occurrence. Fossil scorpions are recorded in the coal formation of Chomle, in Bohemia. Among the radiated animals and zoophytes (to which belong the very earliest vestiges of animated being) are a great variety of very remarkable and exquisitely beautiful forms, those for instance, of the encrinites, apiocrinites, and actinocrinites which have more resemblance to plants than animals, whence their name of "stone lilies." They seem to have attained their maximum in the carboniferous period. The pentacrinites of the lias are particularly beautiful. Sea urchins (echini) first appeared in the lias period, became abundant in the oolitic, continued so during the cretaceous epoch, and are still denizens of our seas. Corals and corallines belong to every age in which limestones have been formed.

(440.) *Fossil Plants.*—The lowest palæozoic strata exhibit indications of what may be taken for sea-weed, and in the grauwacke strata (which belong to these and to the lower Devonian), fucoid plants occur abundantly. In Pennsylvania a hundred layers of them have been found in a thickness of 20 feet (Buckland, *Bridgw. Tr.* i., 452), but it is not till the carboniferous period that fossil vegetation assumes any notable proportions. There, however, it stands forward in most singular and wonderful prominence, as there is no doubt that the whole of the immense deposits of coal in every part of the world owe their origin entirely to the fossilization of vegetables.

"The most elaborate imitations of living foliage," says Dr. Buckland, "upon the painted ceilings of Italian palaces, bear no comparison with the beauteous profusion of extinct vegetable forms with which the galleries of the Bohemian coal mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage flung in wild profusion over every part of its surface. . . . Trees of forms and characters now unknown, are presented to the spectator almost in the beauty and vigour of their primeval life. Their scaly stems and bending branches, with their delicate foliage, are all spread before him, little impaired by the lapse of countless ages." The plants thus wonderfully preserved are equisetaceæ, ferns, mostly arborescent (indicating the prevalence of a tropical climate and insular arrangement of the land), lepidodendra, sigillaria, calamites, and stigmaria, the lepidodendra offering a transitional step between cryptogamous and flowering plants of high botanical interest. Above the carboniferous series the vegetation undergoes a great change. Cycadeæ occur in abundance, associated with peculiar ferns, but now coniferous plants, such as pines, araucarias, etc., begin to appear in the lias and oolite; and it is singular that the genera in our own lias approximate rather to the recent species of the southern than the northern hemisphere. It is worthy of remark, that where the stumps of these trees are found rooted in strata now

inclined at a high angle to the horizon, the direction of the remaining portion of the stem is similarly inclined to the vertical. The pandaneæ, or screw pines (now confined to the Indian archipelago and tropical Pacific islands), are also found in our oolitic beds.

(441.) In the tertiary strata, the Dicotyledons assume nearly the same ratio to the Monocotyledons as at present, and the greater number of fossil plants, though of extinct species, bear much resemblance to living genera. Great deposits of Brown Coal or Lignite (as those of Poole in Dorset, Bovey Tracey in Devon, Soissons in France, the Surturbrand beds in Iceland, and those on the banks of the Rhine), belong to the Eocene epoch, those of Oeningen in Switzerland to the Meiocene. Independent of these, we find fossil palms in the British tertiary beds, and even the date and cocoa-nut in the isle of Sheppey, as well as at Brussels, where also the fruit of the areca-nut is found fossil, but with abundant evidence of having been drifted thither by oceanic currents from a warmer climate.

(442.) As we approach the recent epochs, the remains of vegetables are assembled in *submarine forests*, such as we find at Hastings, on the coast of Sussex, and indeed along the shores of western Europe, from Scandinavia to Spain and Portugal. They stretch sometimes inland under gravel sands and clays to a considerable distance, usually on slopes dipping slightly seaward. In the Baltic, trunks of oaks, pines, etc., the roots in their

natural position, several layers one above the other, and four or five feet under water, occur at Griefswald, in the island of Usedom, and near Colberg. In the submarine forest of Minehead, Somerset, the bones and antlers of the red deer (which are still found wild in Exmoor) are found among the still upright oak stumps. In one of these forests in South Wales, near the mouth of the Neath river, among the stumps are found footmarks of a gigantic species of ox in the clay, apparently of the "*Bos primigenius*," whose horns and skull have been discovered near the spot.

(443.) A great portion of the fossilized plants which occur in various parts of the world, are found silicified, the vegetable matter having been, as it were, extracted molecule by molecule, and silex deposited in its place, and that without destroying the cells, fibres, and tissues of the organization, which remains perfectly distinguishable under the microscope, in sections thin enough to be transparent. The chemical or electro-chemical process by which this change has been accomplished, is ill understood. Whatever the nature of the process, it goes on, as it were, under our eyes in siliceous springs; as in the Azores, where wood and reeds are found to become silicified; in the Geysers of Iceland; and even in the waters of certain streams not usually considered siliceous, as in the case of Trajan's bridge, the piles of which, still extant in the Danube, are externally converted into silex. But

other cases occur where the mode of change is much more mysterious. Thus in the sand of the Isthmus of Suez, an immense abundance of silicified palm-trees makes its appearance, which would seem never to have undergone submergence in water. At Ober Dollendorf, on the Rhine, occurs a deposit of silicified wood, in which not only the living organization of the wood is preserved, but when the wood has become decayed, and almost disintegrated by decomposition, the silicifying process has arrested the progress of decay, and preserved every fibre in *loose spiculæ* of most wonderful delicacy and beauty.

ETHNOLOGY.

(444.) Our limits oblige us to be very brief on this part of our subject, and in this we acquiesce the more readily—1st, Because the reader will find, under that heading, an elaborate article in another part of this work;* and 2dly, Because whatever *properly* belongs to the scope of the present essay, may be comprised in a very small compass. And first, then, as to the date of the introduction of the human species on earth. So far as geological research has hitherto gone, there can hardly be said to be any *absolute unequivocal proof* that men have been coeval with any one quadruped now extinct, or any bird but the dodo and the soli-

* The Encyclopædia Britannica—See the Introduction.

taire or blue-bird, whose extinction is distinctly referable to his agency in times comparatively recent. The geologist, however, needs not to be reminded that this admission leaves a margin wide enough for any, even the most extravagant interpretations, of sacred chronology or traditional history.* 3dly, That the unity of the human species, as a matter of natural history, rests upon quite as valid physiological arguments as that in the case of several other animals, of the dog, for instance, among quadrupeds, or the domestic fowl among birds (to say nothing of the sheep and ox, in which the varieties are less marked), and in which the "races" are distinctly referable to the influence exercised by their domestication and *association with man;* not only as to varieties of stature or form (which go to an infinitely greater extent than anything observable among different races among men), but as to the development of new and peculiar psychological qualities.† Of all the merely physiological arguments which have been adduced in support of this unity, the most satisfactory seems to be that drawn from the identity of the period of gestation in all the races of

* [The late discoveries of flint implements, indisputably of human formation, in immense abundance in the gravel diluvium near Abbeville, and the careful investigation the subject has undergone, seem to have placed this statement beyond cavil, and to have rendered the co-existence of man with at least some of the most recently extinct quadrupeds very far from improbable.]

† It is probable that the full value of the Elephant as an intelligent servant of man has never been developed, owing to the neglect of all

mankind. 4thly, That, nevertheless, the difference between the human and all other species of animals is so vast, that it is impossible to ground a perfectly secure inductive argument on any such analogies. Our definition of "species" breaks down: and 5thly, That though we have absolutely no measure whatever, and cannot even conjecture what time or what number of generations would be required to convert the descendants of (say) a Georgian or a Circassian pair, established in Congo or Guinea, and cut off from all communication with the rest of mankind, into negroes, or *vice versa*; we are very sure that the change would require an immense period; and yet that such transformation, if it ever took place at all, must have taken place antecedent to all history. The negro was as much a negro in the time of the Romans as at the present day. The fair hair and blue eyes of the Germanic races were as much matter of general notoriety and contrast with the dark standard of South Italian beauty (*nigris oculis, nigroque crine*) in the days of Juvenal * as now. If, therefore, we accept the idea of a single creation, and of the divergence of the human race on the world from a single

ational and persevering attempts to breed them in captivity. An absurd prejudice has too long been suffered to prevail as to its impossibility, but this has been distinctly disproved, and is now, we believe, exploded. The wonderful sagacity and *attachability* of the Seal might render him most useful and valuable servant as a *sea-dog*.]

* Cærula quis stupet Germani lumina, flavam Cæsariem.

centre; since we must then make up our minds to accept with it whatever consequences, as to the great duration of man's denizenship on earth, the existing diversity of races shall carry with it, we must not be surprised if those should be found who maintain that every trace of the primeval language has been totally obliterated indefinite ages ago, and that, whatever clue language may afford us in tracing out migrations and affiliations during the last few thousands of years, it can give us absolutely none towards the discovery of that point or that region on the surface of our planet first inhabited by man. All that the division recognized by ethnologists of the existing population of the globe into three, or five, of more races differing by marked peculiarities (a Caucasian or Aryan, a Mongolian and a Negro, or these with an American or Polynesian type), can teach us is, that certain great districts, having certain features more or less influential in determining moral and physical habits, have remained for a sufficient number of ages in a state of comparative insulation from each other. On this subject we must refer our readers emphatically to the great work of the late Dr. Pritchard on "the Natural History of Man," [and to the recent excellent article in the *Revue des deux Mondes* on the Natural History of Man, and the unity of the human species, by M. de Quatrefages].

(445.) We cannot conclude without acknowledg-

ing our obligations to the authors of several valuable and excellent works on this very general subject which we have consulted, and which have furnished us with useful guidance, especially the Physical Atlas of Mr. Keith Johnston, a perfect treasure of compressed information; Mrs. Somerville's "Physical Geography," and the unpretending but most useful treatise on the same subject by Professor Ansted, in the "Manual of Geographical Science." To cite the special authorities from which we have drawn the great mass of our statements, or to which the reader must be referred for further information, would be almost equivalent to giving a *catalogue raisonée* of voyages, travels, and works on geology, geography, and natural history.

APPENDIX.

APPENDIX A.

TABLE OF THE HEIGHTS OF MOUNTAINS.

I. Mountains of Europe.

N B.—When the heights in this table differ from the text, the former are to be preferred. (V) denotes an active volcano.

Mountains of Europe.	Height in English feet.	Country or District.
Mont Blanc	15,744	Sardinia.*
Monte Rosa	15,151	Sardinia.
Zumsteinspitze (Monte Rosa), B .	15,004	Sardinia.
Signalkuppe (Monte Rosa), B .	14,964	Sardinia.
Dom, B	14,935	Sardinia.
Lyskamm, B	14,889	Sardinia.
Mont Cervin (Matterhorn) . .	14,836	Sardinia.
Weisshorn, B	14,804	Sardinia.
Taescherhorn, B	14,758	Sardinia.
Parrotspitze (Monte Rosa), B .	14,577	Sardinia.
Dent Blanche, B	14,322	Sardinia.

* [This list was for the most part made out before the cession of Nice and Savoy to France. Sardinia is retained as the "country or district," partly to avoid confusion in comparing this with the list in the Encyclopædia Britannica, and partly by reason of the difficulty of determining on which side the new frontier line several of the summits indicated actually lie, in the absence of very precise charts laid down for the purpose. The heights marked B are of recent determination by M. Betemps, obligingly communicated to us by J. Ball, Esq., M.P.]

Mountains of Europe.	Height in English Feet.	Country or District.
Ludwigshöhe, B	14,187	Sardinia.
Finsteraarhorn	14,026	Switzerland.
Zwillinge (s), B	13,879	Sardinia.
Rothhorn (*Moming*), B	13,852	Sardinia.
Alphubel, B	13,803	Sardinia.
Rimpfischhorn, B	13,790	Sardinia.
Strahlhorn, B	13,750	Sardinia.
Jungfrau	13,716	Switzerland.
Dent D'Herens, B	13,714	Sardinia.
(Breithorn) *	13,703	Sardinia.
Monte Viso	13,599	Sardinia.
Grande Jorasse (Mt. Blanc)	13,496	Sardinia.
Pic des Ecrins or Arsines (Mont Pelvoux)	13,467	France.
Aiguille Verte (Mt. Blanc)	13,432	Sardinia.
Zwillinge (*n*), B	13,432	Sardinia.
Schreckhorn	13,397	Switzerland
Ober Gabelhorn	13,366	Sardinia
Mt. Iseran (La Levanna)	13,272	Sardinia.
Aiguille du Geant (Mt. Blanc)	13,099	Sardinia.
Oertler Spitz (Monte Cristallo)	12,822	Tyrol.
Klein-Matterhorn, B	12,749	Sardinia
Cima di Jazzi, B	12,527	Sardinia
Gross Glockner	12,431?	Austria.
Tête Blanche, B	12,307	Sardinia
Trifthorn, B	12,261	Sardinia.
Mulhaçen	11,664	Spain.
Stockhorn, B	11,595	Sardinia.
Pico de Veleta	11,398?	Spain.
La Marmolata	11,350	Tyrol.
Malahite	11,168	Pyrenees
Unter Gabelhorn, B	11,149	Sardinia.
Grand Rioburet	11,063?	Austria.

* By a barometrical measurement in 1821 by the author [The point ascended was probably the Breithorn, the local guides employed being for the most part ignorant of the true designations of the peaks. In the list printed in the Encyclopædia Britannica this summit is called the Kleine Mont Cervin, which is nearly 1000 feet lower.]

Mountains of Europe.	Height in English feet.	Country or District.
Mont Perdu	10,994	Pyrenees.
Muschelhorn	10,948?	Tyrol.
Cylinder of Maburé . . .	10,897	Pyrenees.
Etna (V)*	10,872	Sicily.
Maladetta	10,866	Pyrenees.
Vignemale	10,820	Pyrenees.
Bösentrift, B	10,603	Sardinia.
Sierra de Grodo . . .	10,552	Spain.
Hochspitze	10,330	Vorarlberg.
Dreyherrn Spitz . . .	10,122	Austria.
Monte Corno (Gran Sasso d'Italia)†	10,144	Apennines.
Mt. Buet	10,112?	Sardinia.
Sharah Tagh	10,000	Eur. Turkey.
Ruska Poyano	9,912	E. Carpathians.
Olympus in Europe . . .	9,749	Thessaly.
Gross Kogl	9,700?	Carinthia.
Monte Santo	9,628	Greece.
Mt. Budosch	9,594	Transylvania.
Mt. Surrul	9,593	E. Carpathians.
Pic du Midi	9,439	Pyrenees.
Mt. Terglou	9,366	Austria.
Mt. Butschetje	9,256	Transylvania.
Mt. Legnone	9,206	
Cima d'Asta	9,194	Tyrol.
Canigou	9,138	Pyrenees.
Mte. Amaro di Majella . .	9,113	Apennines.
Mount Kom	9,000?	Illyria.
Great Balkan (Hæmus) . .	8,874	Balkan Mts.
Lomnitzer Spitz (Tatra Groupe) .	8,862	N. Carpathians.
Monte Rotondo	8,767	Corsica.
Monte d'Oro	8,701	Corsica.
Mt. Tatra	8,524	N. Carpathians.
Mt. Tornavacas	8,500?	Spain.
Mt. Kesmark (Tatra Groupe) .	8,500?	Hungary.

* By a barometrical measurement in 1824 by the author.

† Schouw makes the Monte Corno 9521 feet. This seems more probable. It is difficult to credit the existence of summits even so lofty as 9000 feet in the Apennine range.

Mountains of Europe.	Height in English feet.	Country or District.
Pic d'Abrizon	8,344	Pyrenees.
Mt. Csabi	8,316	W. Carpathians.
Lipsze	8,314	Carpathians.
Rilodagh (Rhodope)	8,313	
Mt. Guiona	8,241	Greece.
Pena Lara	8,222	Spain.
Mont Spinal	8,203	Tyrol.
Schneehätten *	8,102	Scandinavia.
Skägtoltind	8,101	Scandinavia.
Parnassus	8,068	Greece.
Schlern	8,045	Tyrol.
Taygetus (Mt. St. Elias)	7,904	Greece.
Monte Gazza	7,898	Tyrol.
Mte. Velino	7,851	Apennines.
Mt. Kelmos	7,726	Greece.
Cima di Portole	7,416	Tyrol.
Mt. Olonas	7,293	Greece.
Siete Picos	7,244	Spain.
Koldetina	7,224	Scandinavia.
Termenillo Grande	7,212	Apennines.
Sognefield	7,182	Scandinavia.
Pindus	7,000	Greece.
Monte Cimone	6,975	Apennines.
Pighätten	6,788	Scandinavia.
Mt. Athos	6,776	Greece.
Langfield	6,598	Scandinavia.
Le Molesson	6,584	Jura.
El Gador	6,575	Spain.
Mt. Priel	6,565	Austria.
Pizzo di Cane	6,509	Sicily.
Monte Genargentu	6,293	Sardinia. (Isl.)
Mont Ventoux	6,263	France.
Pic de Sancy (Mt. d'Or)	6,238	France.
Sulitelma	6,178	Scandinavia.
Plomb du Cantal	6,096	France.
Mont Rigi	6,050	Switzerland.

* K. Johnston makes the Schneehätten 7620. We follow the Annuaire du Bureau des Longitudes.

Mountains of Europe.	Height in English feet.	Country or District.
Aetscher	5,990	Austria.
Mont Mezen (Cevennes)	5,794	France.
Monte Amiata	5,794	Tuscany.
Mount Helicon	5,738	Greece.
Delphi	5,725	Greece.
Sierra d'Estrella	5,578	Portugal.
Mont Lozere	5,535	Central France.
Puy Mary	5,435	Central France.
Riesekoppe	5,394	Germany.
Wechselsberg	5,352	Styria.
Mt. Hussoko	5,328	Moravia.
Schneekoppe	5,376	Bohemia.
Puy de Violan	5,229	Central France.
Kasberg	5,215?	
Mt. Adelat	5,145	Sweden.
Tschatir Dagh	5,000	Crimea.
Riesenberg	4,961	Bohemia.
Melderskin	4,859	Scandinavia.
Gross Arberg	4,832	Bavaria.
Puy de Dome	4,807	Central France.
Schneeberg	4,784	Riesengebirze.
Ballon des Vosges	4,688	France.
Feldberg (Schwartzwald)	4,675	Germany.
Belchenberg (Schwartzwald)	4,642	Germany.
Rachelberg Bohmerwald	4,561	Germany.
Mt. Celene (Kyllene ?)	4,500?	Greece.
Ben Nevis	4,406	Scotland.
Lyngen Mountains	4,300	Scandinavia.
Ben Macdui	4,296	Scotland.
Kammkoppel (Schwartzwald)	4,265	Germany.
Cairn Toul (Aberdeen)	4,225	Scotland.
Puy de Longchamp	4,190	Central France.
Puy de Come	4,173	Central France.
Kandelberg (Schwartzwald)	4,160	Germany.
Sonnenwerbel (Erzgebirge)	4,124	Germany.
Cairn Gorm	4,090	Scotland.
Puy de Pariou	4,012	Central France.
Puy de Cliersou	3,992	Central France.

Mountains of Europe.	Height in English feet.	Country or District.
Ben Lawers	3,984	Scotland.
Vesuvius (V)*	3,922	Italy.
Puy de Chopine	3,910	Central France.
Mt. Eryx	3,894	Sicily.
Mte. Somma	3,869	Italy.
Ben Avon (Aberdeen) . .	3,821	Scotland.
Grand Sarcouy	3,799	Central France.
Brocken (Hartz)	3,740	Germany.
Sierra de Foya (Algarve) . .	3,609	Portugal.
Mt. Rona	3,593	Shetland.
Snowdon	3,590	N. Wales.
Schehallion†	3,547	Scotland.
Steinberg (Moravia) . . .	3,511	Germany.
Cairn Llewellen	3,471	N. Wales.
Schneeberg (Fichtelgebirge) .	3,461	Germany.
Mte. Cuccio (Palermo)‡ . .	3,435	Sicily.
Ben Wyvis	3,422	Scotland.
Curran or Cairn Tual (Kerry) .	3,405	Ireland.
Hymettus	3,378	Greece.
Gross Bier (Thuringia) . .	3,361	Germany.
Cuchullin (Skye)	3,242	Hebrides.
Ben Lomond	3,192	Scotland.
Ben More (Mull)	3,185	Hebrides.
Mte. Cavo (Campagna) . .	3,130	Italy.
Helvellyn (Cumberland) . .	3,115	England.
Skiddaw (Cumberland) . .	3,058	England.
Cader Idris	2,959	N. Wales.
Chicciola (V) (Stromboli) . .	2,957	Lipari Islands.
Cross Fell (Cumberland) . .	2,928	England.
Sliebh Donard	2,788	Ireland.
Gross Feldberg (Taunus) . .	2,775	Germany.
Blessberg (Thuringia) . .	2,748	Germany.
Cheviot	2,669	England.
Coniston Fell (Lancashire) .	2,649	England.
Nephin (Mayo)	2,638	Ireland.

* By a barometrical measurement by the author.
† We follow the Annuaire du Bureau des Longitudes.
‡ By a barometrical measurement by the author, June 23, 1824.

Mountains of Europe.	Height in English feet.	Country or District.
Morne Mountains (Down) . .	2,493	Ireland.
Schunner Fell (Yorkshire) .	2,348	England.
Soracte (Sorretto) . . .	2,271?	Italy.
Skaling Fell (Stromoe) . .	2,172	Feroe Islands.
Ben More (South Uist) . .	2,035	Hebrides.
Löwenberg (Siebengebirge) .	2,024	Germany.
Hecla (South Uist) . . .	1,992	Hebrides.
Mt. Ronas (Shetland) . .	1,475	Scotland.
Gibraltar	1,439?	Spain.
Volcano Island (V) . . .	1,304	Lipari Islands.
Valdai Mountains (culm.) . .	1,100	Russia.
Arthur's Seat (Edinburgh) .	822	Scotland.

2.—Mountains of Asia.

Mountains of Asia.	Height in English feet.	Country or District.
Deodunga or Chingo-Pamari .	*29,002	Nepal.
Kinchinjunga (W. peak) . .	28,178	Sikkim.
——— (E. peak) . .	27,826	Sikkim.
Dwalagiri	26,861*	Nepal.
Nandadevi	25,749	Himalaya.
Juwahir	25,669	Kemaon.
Jumnotri	25,660	Nepal.
Jumnu	25,313	Sikkim.
Setghur	25,261	Nepal.
Daibhun	24,740	Nepal.
Gossain Thau	24,700	Himalaya.
Khabru	24,005	Sikkim.
Chumalari	23,929	Thibet.
Momonangli or Gurla . .	23,510	Thibet.
Webb's Peak, No. 12 . .	23,263	Himalaya.
Powhunri or Donkiah Lah .	23,175	Sikkim.

* We follow the Annuaire du B. des L. K. Johnston makes it 27,600.

Mountains of Asia.	Height in English feet.	Country or District.
Webb's Peak, No. 3 . . .	22,832	Himalaya.
Api	22,799	Nepal.
Webb's Peak, No. 23 . .	22,727	Himalaya.
———— St. Patrick . .	22,638	Himalaya.
———— St. George . .	22,500	Himalaya.
———— No. 13 . . .	22,313	Himalaya.
———— No. 25 . . .	22,277	Himalaya.
Kanchangow	22,000	Sikkim.
Jownili	21,940	Kemaon.
Zwillinge	21,600	East Himalaya.
Demawend (V) . . .	21,500*	Persia.
Ganguutri Pyramid . . .	21,219	Himalaya.
Kailas	21,000	Thibet.
Hindu Koh (Summit N. of Cabul)	20,232	Affghanistan.
Bolor Mountains . . .	19,000	
Elbruz	18,493	Caucasus.
Kohibaba	17,905	Hindu Kho.
Ararat (Agridagh) . . .	17,112	Persia.
Kasbek	16,532	Caucasus.
Klieutschewsk (V) . . .	15,763	Kamschatka.
Savalan . . . ? . .	15,750	Caucasian Mts.
Argæus (Argisch Taugh) .	13,197†	Asia Minor.
Opalinski (V), 51. 21. N. . .	12,000	Kamschatka.
Jebel el Makmel . . .	12,000	Syria.
Uschinskaia (V) . . .	11,721	Kamschatka.
Koriaskaia (V)	11,210	Kamschatka.
Belouka	11,062	Altai.
Takt-i-Suleiman	11,000	Affghanistan.
Tangnou Mountains (Oubsa River)	11,000	Central Asia.
Kronozkaia (V)	10,609	Kamschatka.
Schiwelutsch (V) . . .	10,544	Kamschatka.
Hermon	10,000	Syria.
Taurus (culminating point) .	9,800	Asia Minor.

* Set down in Encyclopædia Britannica 14,695. Humboldt (Kosmos, iv. 335) makes Demawend more than 19,000 feet. Mr. Thomson and Lord Schomberg Kerr are said to have determined its height by recent barometrical measurement at 21,500 feet—(*Times Newspaper*). M. Khanikoff's trigonometric measures corroborate this rec[illegible].

† Humboldt makes it 12,600. We follow Mrs. Somerville.

Mountains of Asia.	Height in English feet.	Country or District.
Krestowskaia	9,592	Kamschatka.
Libanus	9,517?	Syria.
Um Shomah	9,300	Syria.
Jupanowa (V)	9,055	Kamschatka.
Awatscha or Gorelaia (V) . .	8,910	Kamschatka.
Dodabetta Peak . . .	8,760	Nilgheri Mts.
Horeb	8,593	Syria.
Kudiakad Peak . . .	8,502	Nilgheri Mts.
Bevoybetta Peak . . .	8,488	Nilgheri Mts.
Murkurti	8,402	Nilgheri Mts.
Daversolabetta Peak . . .	8,380	Nilgheri Mts.
Kundah	8,353	Nilgheri Mts.
Tolbatschuskaia (V) . . .	8,313	Kamschatka.
Poworotnoi (V) . . .	7,931	Kamschatka.
Kundamaya	7,816	Nilgheri Mts.
Sinai	7,498	Syria.
Wiljutschinskaia (V) . .	7,373	Kamschatka.
Utacamund Peak . . .	7,361	Nilgheri Mts.
Tamburbetta Peak . . .	7,292	Nilgheri Mts.
Hokulbetta Peak . . .	7,267	Nilgheri Mts.
Bonasson	7,000	Western Ghauts.
Urbetta	6,915	Nilgheri Mts.
Kodanad	6,815	Nilgheri Mts.
Jebul Serbal	6,760	Syria.
Wilutschinskaia (V) . . .	6,746	Kamschatka.
Davebetta	6,571	Nilgheri Mts.
Kotagiri	6,571	Nilgheri Mts.
Kundabetta	6,555	Nilgheri Mts.
Olympus in Asia . . .	6,332	Asia Minor.
Dimhutti	6,330	Nilgheri Mts.
Cunur	5,886	Nilgheri Mts.
Tandiamole	5,781	Western Ghauts.
Pupugiri	5,682	Western Ghauts.
Koniakofsky Kamen . .	5,397	Ural.
Tremel or Iremel . .	5,075	Ural.
Mount Abu	5,000	Aravulli Mts.
Constantinow Kamen . .	5,000	Ural.
Jatara	4,800	Affghanistan.

Mountains of Asia.	Height in English feet.	Country or District.
Mahabuleshwar	4,700	Western Ghauts.
Purundar	4,472	Western Ghauts.
Singhur	4,162	Western Ghauts.
Hurrechundernagur . . .	3,894	Western Ghauts.
Taganai	3,592	Ural.

3.—Mountains of Africa and the Atlantic Islands.

Mountains of Africa and the Atlantic Islands.	Height in English feet.	Country or District.
Kilimanjaro	20,000	Equatorial Africa.
Mount Woso, 6° 30′ N. . .	16,350	Ethiopia.
Mount Dajan, 13° 15′ N. . .	15,740	Ethiopia.
Abba Jarrat, 13° 10′ N. . .	15,008	Abyssinia.
Geesh	15,000?	Abyssinia.
Buahat, 13° 12′ N. . . .	14,362	Abyssinia.
Mont Fatra, 10° 42′ N. . .	14,350	Abyssinia.
Cameroon Mountains . .	13,000	Bight of Biafra.
Pico de Teyde (V) (Teneriffe) .	12,205	Canary Islands.
Atlas (Miltsin)	11,400	Morocco.
Lamalmon	11,200?	Abyssinia.
Fez Mountains	10,000?	Morocco.
Chahorra (V) (Teneriffe) . .	9,885	Canary Islands.
Peak of Fogo (V) . . .	9,152	Cape Verde Is.
Peak of St. Antonio . . .	8,815	Cape Verde Is.
Gondar Mountains . . .	8,450?	Abyssinia.
Tristan d'Acunha (V) . .	8,236	T. d'Acunha Is.
Taranta	7,800?	Abyssinia.
Pico de Cruz (Palma) . .	7,730	Canaries.
Pico (Peak of Azores) . .	7,613*	St. Michael's. Azores.
Trigo	7,400?	Canaries.
Blue Mountains (culmination of)	7,277†	Jamaica.

* Keith Johnston makes this mountain 7808 feet. We follow Humboldt.
† Keith Johnston gives 6000. We follow the Annuaire du B. des Long.

Mountains of Africa and the Atlantic Islands.	Height in English feet.	Country or District.
Montano del Cobre . . .	6,890	Cuba.
Beerenberg	6,874	Jan Mayen's Is.
Los Rexas (Gt. Can.). . .	6,400	Canaries.
Morne Diablotin (V). . .	6,075	Dominica.
Pico Ruivo	6,059	Madeira.
Mount Chaco	6,000	Hayti.
Oraefa Jokul (V) . . .	5,927	Iceland.
Eyafialla (V)	5,685	Iceland.
Hecla (V)	5,117*	Iceland.
Snaefell Jokul	5,112	Iceland.
Morne Garou	5,007†	St. Vincents.
Souffriere (Guadaloupe) . .	4,867‡	
Montagne Pelée or Carbet . .	4,432§	Martinique.
Alto Geraona (Gomera Is.). .	4,400	Canaries.
Swartz Spitz (Pte. Noire) . .	4,399	Spitzbergen.
Mount Parnassus . . .	3,917	Spitzbergen.
San Anton (Ferro) . . .	3,907	Canaries.
Table Mountain . . .	3,816	Cape of G. Hope.
Mount Misery (St. Kitts) . .	3,720	Antilles.
Pico de Vara (St. Michaels) .	3,570	Azores.
Caldeira de S. Barbara (Terceira)	3,500	Azores.
Pico de S. Jorge	3,498	Azores.
Morra Gordo (Flores) . .	3,087	Azores.
Asses' Ears (Fuentaventura) .	2,770	Canaries.
Diana's Peak	2,692?	St. Helena.
Caldeira de Corvo . . .	2,460	Azores.
Lion's Head	2,166?	Cape of G. Hope.
Santa Lucia (V)	1,920	Antilles.
Mount Esk (V)	1,600	Jan Mayen Is.
Morne Rouge (V) (Granada) .	640	Antilles.

* The Annuaire makes Hecla only 3314. We follow Humboldt.
† Mrs. Somerville makes Mt. Garou only 4370. We follow Keith Johnston.
‡ According to St. Clair Deville. K. Johnston makes it 5110.
§ Dupuger makes this mountain 4706 feet high. We follow Keith Johnston.

4.—Mountains of America.

Mountains of America.	Height in English feet.	Country or District.
Aconcagua	23,910	Chile.
Sahama (V)	22,350	Peru.
Parinacota	22,030	Peru.
Tupungato	22,016	Chile.
Gualatieri	21,960	Peru.
Pomarape	21,700	Peru.
Chimborazo	21,424	Equatorial Andes.
Sorate	21,288	Bolivian Andes.
Ilimane	21,148	Bolivian Andes.
Chaquibamba	21,000	Bolivian Andes.
Viejo	20,500	Peru.
Concae	20,386	Chile.
Chachacomani	20,355	Bolivian Andes.
Huaina (Potosi) . . .	20,260	Bolivian Andes.
Angel Peak (16. 10. S.) . .	20,115	Bolivian Andes.
Chipicani . . .	19,745	Peru.
Charcani (V) . . .	19,708?	Peru.
Coyambe	19,535	Equatorial Andes.
La Mesada	19,356	Bolivian Andes.
Antisana (V)	19,137	Quito.
Sierra de Santa Marta . .	19,000	Venezuela.
Cotopaxi (V)	18,877	Equatorial Andes.
Arequipa (V)	18,876?	Peru.
Quenuta, 17. 41. S	18,765	Peru.
Nevado of Anaclache . .	18,500	Peru.
Cacaca, 16. 25. S. . . .	18,210	Bolivian Andes.
Tolima	18,120	Quito.
Cololo	17,930	Bolivian Andes.
Orizaba (V) or Citlaltepetl .	17,879	Mexico.
Mount St. Elias* . . .	17,850?	N. W. America.
Popocatepetl (V)	17,726	Mexico.
Maypu (V)	17,644	Chile.
Apu Cunaranu . . .	17,590	Peru.

* According to Captain Denham, Mount St. Elias is only 14,968 feet in height.

Mountains of America.	Height in English feet.	Country or District.
Vilcañota	17,525	Peru.
Ilinissa	17,380	Equatorial Andes.
Sangay (V) or Macas . .	17,124	Quito.
Puracé (V)	17,006	N. Granada.
Mount Hooker (Rocky Mountains)	16,730?	N. W. America.
Chorolque	16,550	Bovilian Andes.
Tunguragua (V) . . .	16,491	Quito.
Sinchulagua	16,434	Quito.
Cerra de Potosi	16,152	Bolivian Andes.
Miriquiri	16,100	Bolivian Andes.
Dona Aña Peak . . .	16,070	Bolivian Andes.
Nevado de la Vinda . . .	16,000	Peru.
Uvinas	16,000	Bolivian Andes.
Mount Murchison (Devil's Peak)	16,000	N. W. America.
Mount Brown (Rocky Mountains)	15,990	N. W. America.
Pichincha (V)	15,923	Quito.
Iztacihuatl (V)	15,705	Mexico.
Carguairazo	15,673	Quito.
Cumbal (V)	15,680	Quito.
Mt. St. Helens (Cascade Mountains)	15,500	N. W. America.
Mount Hood (Cascade Mountains)	15,500	N. W. America.
Sierra Nevada	15,170	Mexico.
Toluca (V)	15,168	Mexico.
Tupungate (V)	15,100	Chile.
Agua (V)	15,000	Guatemala.
Cerro di Buen Tempo . .	14,710	N. W. America.
Monte de las Litanias . .	14,500	Bolivian Andes.
Inchocaio	13,656	
Fremont's Peak, Rocky Mountains	13,568	N. W. America.
Pasto	13,450	Quito.
Monte de Azupo . . .	13,450	
Cope de Perote	13,416	Mexico.
Amilpas, 15. 10. N. . .	13,160	Guatemala.
Colima (V)	13,003	Mexico.
Tuqueres (V)	12,821	Los Pastos.
Atitlan (V)	12,506	Guatemala.
Mont Regnier (V)	12,320	Cascade Mountains, N. W. A.

Mountains of America.	Height in English feet.	Country or District.
Mount Taylor	12,256	Rocky Mountains, N. W. A.
Ilämän (V) 60. N. . . .	12,066	N. W. America. Cook's Inlet.
Wrangell's Volcano . . .	12,064	N. W. America. Coppermine R.
Cerro de Azusco . . .	12,052?	Mexico.
Irasu (V. de Cartago) . .	11,478	Guatemala.
St. Nicolaus, 60. 40. N. . .	11,270	N. W. America
Pico de Tancitaro . . .	10,498?	Mexico.
Orosce or Papagajo . . .	9,976	Guatemala.
Votos (V)	9,848	Guatemala.
Viejo (V)	9,600	Guatemala.
Mount Pitt or Laughlin . .	9,549	Cascade Mountains, N. W. A.
Antuco (V)	8,918	Chile.
Silla de Caraccas	8,600	Venezuela.
Mount Aquarius	8,526	Rocky Mountains, N. W. A.
Yanteles (V)	8,030	Patagonia.
Minchinmadeva (V) . . .	8,000	Patagonia.
Sierra de Guayraima . . .	7,600	Venezuela.
Osorno or Lanquihue (V) . .	7,549	Chile.
Corcobado (V)	7,510	Patagonia.
Congrehoy Peak	7,482	Honduras.
Roraima	7,450	Guiaha.
Melimoya	7,400	Patagonia.
Duida*	7,149	Venezuela.
Mount Omoa	7,000	Honduras.
Mount Sarmiento	6,910	Terra del Fuego.
Mount Darwin	6,800	Terra del Fuego.
Mount Washington	6,428	Appalachian Mts., N. A.
Mount Stokes	6,400	Patagonia.
White Mountains, Massachusetts	6,230?	N. America, U.S.
Mount Werner.	6,000?	East Greenland.

* Mrs. Somerville makes Duida 8280 feet. We follow Keith Johnston.

Mountains of America.	Height in English feet.	Country or District.
Blaaserk	6,000?	East Greenland.
Itambe	5,960	Brazil.
Mount Adams	5,960	Appalachian Mts.
Mount Jefferson	5,860	Appalachian Mts.
Sierra de Piedade . . .	5,830	Brazil.
Mount Burney	5,800	Patagonia.
Itacolumi	5,750	Brazil.
High Peak (Adironbeck) . .	5,467	Adironbeck Mts., N.A.
Mount Katahdin	5,360	Maine, U.S., N.A.
Itabira	5,250	Brazil.
Monte Giganta	4,600	California.
Jorullo (V)	4,265	Mexico.
Mount Buckland	4,060	Terra del Fuego.
Cockscomb Mountain . . .	4,000	Honduras.
Monte del Diablo	3,672	SacramentoRiver.
Sierra Ventana	3,500	Buenos Ayres.
Kaatskill Mountains . . .	3,454?	New York, U.S.
Mount Jacinto, 57. 1. N. . .	3,000	N. America.
Guanacaure	3,000	Guatemala.
Mount Edgecumbe, 57. 3. N. .	2,920	Lazarus Island, N.W.A.
Izalco (V)*	2,132	Central America.
Cosiguina (V)	1,000	Guatemala.
Mount Bridgeman (V) . . .	400	South Shetland.

5.—MOUNTAINS OF POLYNESIA, AUSTRALIA, AND PACIFIC ISLANDS.

Mountains of Polynesia, Australia, and Pacific Islands.	Height in English feet.	Country or District.
Singalang (V)	15,000	Sumatra.
Mowna Kia (V)	13,951	Sandwich Isls.
Mount Terror	13,884	South Victoria.

* Keith Johnston assigns 1500 feet for the height of Izalco or Sonsonate. We follow Humboldt.

Mountains of Polynesia, Australia, and Pacific Islands.	Height in English feet.	Country or District.
Mount Ophir (Gunong Pasgama) (V)	13,840	Sumatra.
Mowna Roa (V)	13,758	Sandwich Isls.
Merapi (V)	13,200	Sumatra.
Mount Erebus (V)	12,366	South Victoria.
Rindjani (V)	12,363	Sunda Islands.
Tobreonou	12,250	Otaheite.
Semeru Gunong (V)	12,235	Java.
Fusi-no-yama (V)	12,443	Japan.
Sesarga (V)	12,000	Solomon Islands.
Alaid (V)	12,000	Kurile Islands.
Gunong Dempo (V)	12,000	Sumatra.
Mount Ambotismene . .	11,506	Madagascar.
Gunong Slamat or Tegal (V) .	11,116	Java.
Gunong Ardjuno (V) . .	11,030	Java.
Sumbing or Sunding . .	11,028	Java.
Mount Luse	11,000	Sumatra.
Mowna Wororai or Hualai (V) .	10,790	Owyhee.
Gunong Lavu (V)	10,727	Java.
Walierung (V)	10,300	Java.
Merbabu (V)	10,220	Java.
Gunong Raon (V)	10,180	Java.
Sindoro (V)	9,880	Java.
Gedee (V)	9,850	Java.
Merapi (V)	9,708	Java.
Mount Edgecumbe	9,630	New Zealand.
Schischaldinskoi (V) . . .	8,953	Aleutian Islands.
Mount Egmont	8,840	New Zealand.
Gunong Api (V)	8,800	Sumatra.
Gunong Tengger (V) . . .	8,700	Java.
Lombock Island (V) . . .	8,688	Sunda Islands.
Wielis (V)	8,480	Java.
Mount Pedrotallagalla . .	8,280	Ceylon.
Tchermai (V)	8,280	Java.
Bourbon Island (culm.) (V) .	8,001	Indian Ocean.
Patuha (V)	7,907	Java.
Bukit Tunggul (V)	7,800	Java.
Tomboro (V)	7,600*	Sumbawa.

* Humboldt makes Tomboro only 5862 feet.

Mountains of Polynesia, Australia, and Pacific Islands.	Height in English feet.	Country or District.
Adam's Peak	7,420*	Ceylon.
Sulak (V)	7,204	Java.
Ungarang (V)	7,100	Java.
Papandjam (V)	7,039	Java.
Dasar (V)	7,034	Java.
Klut (V)	7,000	Java.
Mount Koschiusko	6,500	Australia.
Pogromnoi (V)	6,500	Aleutian Islands.
Tankuban Prahu (V)	6,427	Java.
Agung (V)	6,400	Java.
Tongararoro	6,200	New Zealand.
Wayang (V)	6,149	Java.
Tilu (V)	6,062	Java.
Mount Seaview	6,000	New South Wales.
Tombak-ruyung (V)	5,896	Java.
Idjem or Taschem (V)	5,800	Java.
Gunong Lama Lama (V)	5,755†	Ternate.
Mount Lindsay, 28. 20. S.	5,700	Australia.
Burungrang (V)	5,690	Java.
Sumbung (V)	5,582	Java.
Mount Humboldt	5,520	V. Diemen's Land.
Ben Lomond	5,502	V. Diemen's Land.
Mount Dargal	5,490	New South Wales.
Talaya Boda (V)	5,490	Java.
Makutschinskaia (V)	5,474	Aleutian Islands.
Langle	5,350	Japan.
Gunong Lamongan (V)	5,339	Java.
Golgotha (V)	5,263	Java.
Volcano of East Sitkin (V)	5,036	Aleutian Islands.
Atka Island (V)	4,852	Aleutian Islands.
Cradle Mountain	4,700	V. Diemen's Land.
Mount Canoblas	4,610	New South Wales.
Sarytschew (V) Matua Island	4,505	Kurile Islands.
Mount Wellington	4,195	V. Diemen's Land.
Tchikura (V)	4,144	Java.

* Mrs. Somerville sets down Adam's Peak as 6152. We follow Keith Johnston.

† As stated by Humboldt. Keith Johnston sets down the Volcano of Ternate Island at 4098 feet (? if same).

Mountains of Polynesia, Australia, and *Pacific Islands.*	Height in English feet.	Country or District.
Mount Mitchell	4,120	New South Wales.
Wunzen (V)	4,110	Japan.
Mount Pinnabar	4,100	New South Wales.
Mount Arrowsmith	4,075	V. Diemen's Land.
Mount Bathurst	4,000	New South Wales.
Valentine Peak	4,000	V. Diemen's Land.
Ben Nevis	3,910	V. Diemen's Land.
Mount Arthur	3,900	V. Diemen's Land.
Kirauia	3,870	Owyhee.
Mount Sturt	3,735	New South Wales.
Mount Adine	3,726	New South Wales.
Narborough (V)	3,720	Galapagos Islands.
Mount George	3,620	New South Wales.
Mount York	3,440	New South Wales.
Ringitt (V)	3,400*	Java.
Akutan (V)	3,332	Aleutian Islands.
Squall or Sugarloaf Hill	3,288	New South Wales.
Mount Blaxland	3,256	New South Wales.
Mount Tomah	3,240	New South Wales.
Saddle Hill	3,001	New South Wales.
Strzlecki Peak	2,550	Flinders' Island.
Mount Hundawar	2,545	New South Wales.
Mount Munro	2,500	Bass's Strait.
Mount Hay	2,425	New South Wales.
Stony Hill	2,400	New South Wales.
Cockatoo Hill	2,356	New South Wales.
Mount Wilson	2,350	New South Wales
Mount St. Patrick	2,227	V. Diemen's Land.
Assuncion (V)	2,096	Mariana Islands.
Gunung Api (V)	1,948	Banda Island.
Barren Island (V)	1,700	Sunda Islands.
Agatshagak (V)	1,502	Aleutian Islands.
Mount Herschel	1,200	V. Diemen's Land.
Kosima (V)	746	Japan Islands.

* According to Keith Johnston. Humboldt makes it 2345 only.

APPENDIX B.

Lengths, etc., of the Principal Rivers of the World.

N.B.—O. S. G. B. R. are used as contractions of the words Ocean, Sea, Gulf, Bay, River.

Name of River.	Length in Statute miles.	Length in Geographical miles.	Area of River basin in thousands of square Geographical miles.	Sea, Lake, or River into which it flows.
Albany	644	560	...	Atlantic Ocean.
Amazon or Maranon	3545	3080	1512	Atlantic Ocean.
Amur	2739	2380	583	Sea of Japan.
Anadir	460?	400?	63	S. of Kamschatka.
Arkansaw	1840	1599	...	To Mississippi.
	2370	2727	...	To the Sea.
Churchhill	976	848	74	Hudson's Bay.
Colorado	921	800	170	Gulf of California.
Columbia	1565	1360	194	Pacific Ocean.
Connecticut	310	270	8	Atlantic Ocean.
Danube	1722	1496	234	Euxine Sea.
Delaware	304	265	9	Atlantic Ocean.
Dnieper	1243	1080	170	Euxine Sea.
Dniester	505	440	23	Euxine Sea.
Don	1104	960	168	Sea of Azof.
Douro	505	440	29	Atlantic Ocean.
Duna	644	560	33	Baltic Sea.
Dwina	1041	864	106	White Sea.
Ebro	483	420	25	Mediterranean S.
Elbe	787	684	42	German Ocean.
Essequibo	483	420	62	Atlantic Ocean.
Euphrates	1716	1492	196	Persian Gulf.
Forth	120	104	...	German Ocean.
Francisco, St.	1551	1400	187	Atlantic Ocean.
Gambia	700	608	90?	Atlantic Ocean.

Name of River.	Length in Statute Miles.	Length in Geographical Miles.	Area of River basin in thousands of square Geographical Miles.	Sea, Lake, or River into which it flows.
Ganges	1933	1680	432*	Bay of Bengal.
Garonne	368	320	24	Bay of Biscay.
Gihon or Amu	1611	1400	194	Sea of Aral.
Glommen	340	296	...	German Ocean.
Godavery	861	748	93	Bay of Bengal.
Gogra	830	725	...	To the Ganges.
	1440	1250	...	To the Sea.
Guadalquiver	299	260	15	Atlantic Ocean.
Guadiana	483	420	19	Atlantic Ocean.
Hoang-ho	2624	2280	537	Pacific Ocean.
Humber	190	165	...	German Ocean.
Illinois	500	434	...	To Mississippi R.
	1360	1241	...	To the Sea.
Indigirka	1045	908	86	Arctic Ocean.
Indus	2256	1960	312	Arabian Sea.
Irawadi	2532	2200	331†	Indian Ocean.
Jordan	104	90	...	Dead Sea.
Jumna	780	898	...	To Ganges.
	1550	1783	...	To Sea.
Katanga	442	384	...	Bay of Katanga.
Kistna	791	688	82	Bay of Bengal.
Kolyma	921	800	107	Arctic Ocean.
Kour	736	640	65	Caspian Sea.
Lawrence, St.	2072	1800	298	G. St. Lawrence.
Lena	2762	2400	594	Arctic Ocean.
Loire	598	520	34	Bay of Biscay.
Mackenzie	2440	2120	442	Arctic Ocean.
Magdalena	983	828	72	Caribbean Sea.
Maritza	320	278	...	Euxine Sea.
Maykan or Mekong	2417	2100	216‡	China Sea.
Menam	1182	940		Gulf of Siam.

* This includes the basin of the Brahmaputra.
† Including the basin of the Martaban River.
‡ The joint basin of both rivers.

Name of River.	Length in Statute Miles.	Length in Geographical Miles.	Area of River basin in thousands of square Geographical Miles.	Sea, Lake, or river into which it flows.
Minho	221	192	12	Atlantic Ocean.
Mississippi	1930	1677	...	Gulf of Mexico.
Missouri	2310	2008	...	To the Mississippi.
	4096	3560	982*	To Sea.
Motagua	299	260	7	Gulf of Honduras.
Nerbudda	760	660	...	Arabian Sea.
Neva	506	440	67	Gulf of Finland.
Niemen	529	460	32	Baltic Sea.
Niger	1010	878	?	Atlantic Ocean.
Nile	2578	2240	520	Mediterranean S.
Obi	2670	2320	925	G. of Obi, Arctic O.
Oder	552	480	39	Baltic Sea.
Ohio	1200	1043	...	To the Mississippi.
	2270	1973	...	To the Sea.
Oleneck	1151	1000	77	Arctic Ocean.
Orinoco	1556	1352	252	Atlantic Ocean.
Oural	771	670	83	Caspian Sea.
Paraguay	1133	984	...	To Parana River.
	1864	1620	...	To the Sea.
Parana	1500	1304	...	To the La Plata R.
	2265	1968	...	To the Sea.
Paranahyba	857	744	115	Atlantic Ocean.
Petchora	690	600	49	Arctic Ocean.
Piasina	449	390	...	Arctic Ocean.
Plata, La	2210	1920	186	Atlantic Ocean.
Pilcomayo	967	840	...	To Parana River.
	1871	1626	...	To the Sea.
Po	405	352	30	Adriatic Sea.
Potomac	410	357	...	Atlantic Ocean.
Pregel	115	100	6	Baltic Sea.
Pruth	620	538	...	To Danube River.
	740	643	...	To the Sea.

* The joint basin of the whole Mississippi-Missouri river system.

Name of River.	Length in Statute Miles.	Length in Geographical Miles.	Area of River basin in thousands of square Geographical Miles.	Sea, Lake, or River into which it flows.
Red River	1500	1293	...	To Mississippi R.
	1800	1564	...	To the Sea.
Rhine . .	690	600	65	German Ocean.
Rhone . .	644	.560	28	Gulf of Lyons.
Rio del Norte, or Bravo .	2138	1840	180	Gulf of Mexico.
Salado .	829	720	...	Parana River.
	1119	972	...	Sea.
Saskatchewan .	1915	1664	360	Hudson's Bay.
Scheldt . .	180	156	...	German Ocean.
Seine . .	391	340	23	British Channel.
Senegal . .	960	834	?	Atlantic Ocean.
Severn . .	240	191		
Sir or Sihon .	1390	1208	237	Sea of Aral.
Susquehanna .	630	547	...	Atlantic Ocean.
Tagus . .	552	480	22	Atlantic Ocean.
Tarim Ergeugol	940	816	177	Lake of Lob.
Tay . . .	120	104	...	North Sea.
Tchekiang .	1105	960	99	China Sea.
Thaluain or Martaban .	2152	1870	*	Indian Ocean.
Thames . .	220	191	5	British Channel.
Tigris .	1010	878	...	To Euphrates River.
	1100	956	...	To the Sea.
Tocantins . .	1289	1120	285	Atlantic Ocean.
Tonquin . .	552	480	92?	Gulf of Tonquin.
Vardoc . .	270	235	...	Medit. Archipel.
Vistula . .	598	520	57	Baltic Sea.
Volga . .	2762	2400	397	Caspian Sea.
Weser . .	322	280	13	
Yana . .	483	420	...	Arctic Ocean.
Yangtsekiang .	3314	2880	548	Pacific Ocean.
Yenesei . .	3222	2800	785	Arctic Ocean.

* The basin of the Martaban is included in that of the Irawadi.

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N.B.—The references are to the articles as numbered consecutively, and not to the pages. M. stands for mountain, L. for lake, I. for island, V. for volcano, MM. for mountain ranges, II. for groupe of islands, etc.

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